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CHEMICAL & ENGINEERING

NEWS

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Chemistry & Health

Pharmaceuticals among
opportunities addressed by
CHEMRAWN V Page 7

News of the Week

■ **To fight AIDS public health experts urge increased public education and scientific research funding.** Page 4

■ **Stratospheric ozone decrease in Antarctica and elsewhere may be result of high solar activity.** Page 5

■ **Genentech plans to buy out two of its research partnerships.** Page 5

■ **NSF project to establish electronic communication between scientists is now under way.** Page 5

■ **Better monitoring of occupational health data is needed, according to House committee.** Page 6

■ **Tumor necrosis factor appears to have antiviral as well as anticancer activity.** Page 6

Cover: Computer-generated images help drug researchers visualize complex structures; close resemblance in geometry and volume of D-alanyl-D-alanine dipeptide (green and magenta structure) and benzyl-penicillin (blue structure and dot surface) indicates that the two may bind to transpeptidase inhibitors. Photo courtesy of University of Bern and Evans & Sutherland

Letters 2

Concentrates

Business 15

Government 23

Science/Technology 28

The Departments

Books 32

ACS News 35

Awards 41

Newsletters 60

Business

Cytogen, a small biotechnology firm, is now financially secure and racing to develop use of monoclonal antibodies. Page 17

Changes on list of duty-free chemical imports from Third World countries are being considered by U.S. Trade Representative. Page 19

International Business

Propylene use in Western Europe shows strong steady gains, mainly because of increased use of polypropylene. Page 21

Government

Congress approves increase in R&D funding for most agencies; NASA and NIH make biggest gains. Page 24

New Superfund provisions leave industry with many concerns about how smoothly cleanup program will run. Page 26

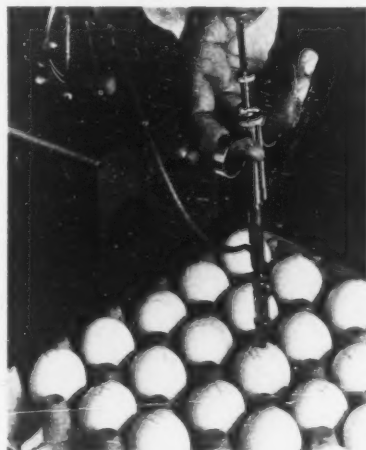
Defense industry buildup will not adversely affect the availability of engineers for nondefense jobs owing to resilient market. Page 27

Technology

World oil problems, including oil price drop, concern U.S. experts at Institute of Gas Technology meeting. Page 29

Science

Stanford University honors former professor at first annual William S. Johnson Symposium in Organic Chemistry. Page 31



News Focus

Fifth CHEMRAWN conference in Heidelberg addresses the role of chemistry in a broad spectrum of health-related topics. Page 7

Propylene Use in Western Europe Showing Steady Gains

Its use to make chemicals, currently growing nearly 3% annually, is increasing faster than ethylene's, is expected to hit 16.5 billion lb in 1990

Dermot A. O'Sullivan, C&EN London

Propylene is something of an orphan in the petrochemical world. Although it is key to a wide range of derivatives, few suppliers set out to make it as their prime product. "Rather, it is everybody's coproduct, or even by-product," Howard E. Browning, marketing manager for olefins, aromatics and bulk petrol at Imperial Chemical Industries' petrochemicals and plastics division, told delegates to the European Chemical Market Research Association meeting in Antwerp.

Although propylene demand is on the rise, mainly because of increasing use of polypropylene, sup-

ply is largely dependent on output from ethylene-making crackers, as well as the economics of oil refinery operations. So price fluctuates widely as availability is "long" or "short."

West European production of propylene last year amounted to about 18.7 billion lb. Some 72%, or 13.4 billion lb, came from crackers, and the remainder from oil refineries. Discounting the nearly 3.1 billion lb used by the refiners themselves, 15.6 billion lb was made available to the chemical industry. An additional 550 million lb or so was imported—mainly from Eastern Europe, Latin America, and the U.S., bringing the total for making chemicals to 16.2 billion lb.

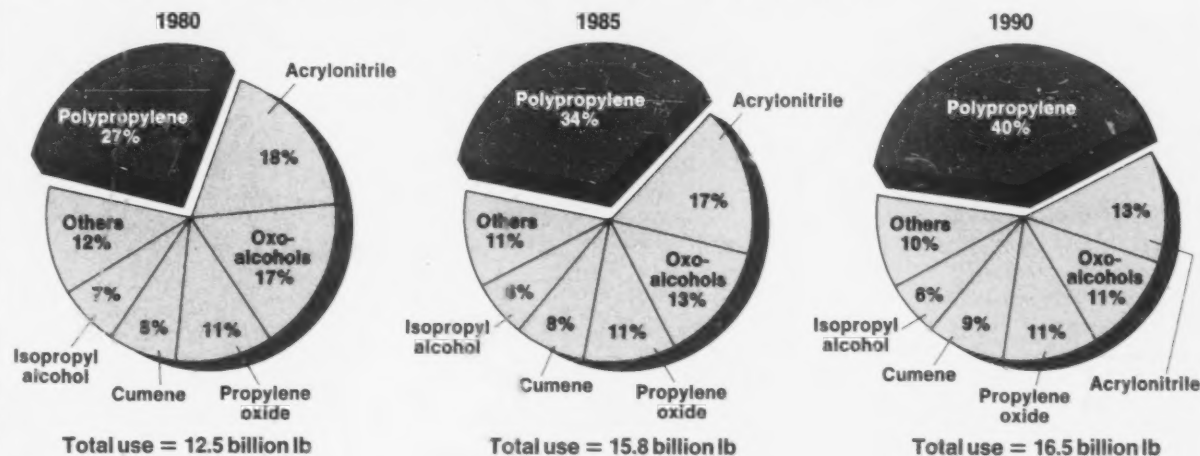
On the demand side, more than 15.8 billion lb went into chemicals in 1985. Polypropylene output absorbed the largest slice (34%), followed by acrylonitrile, oxo-alcohols, propylene oxide, cumene, and isopropyl alcohol, in addition to a variety of chemical operations.

"Polypropylene is the prime engine for propylene growth in Western Europe," Browning observes. "It has been following a classic product life cycle curve ever since its commercialization in the late 1950s, and is still very much in the growth phase. Not only is this true of the product as a whole, but its individual end-use applications are widespread, and all are growing strongly."

He expects West European demand for the polymer to reach 6.6 billion lb in 1990, just about double the nearly 3.4 billion lb consumed in 1980, and representing a 7%-a-year growth over the decade. Moreover, he thinks it likely that production of the polymer will absorb 40% of the propylene used by the European chemical industry in 1990, in contrast to the 27% level in 1980.

As for acrylonitrile and the oxo-alcohols, the markets themselves are reasonably stable. However, increasing efficiency in the use of propylene for their production probably will lead to a decline in the actual

Polypropylene takes growing share of Western Europe's propylene



Source: Imperial Chemical Industries



Browning: everybody's coproduct

amount of the olefin that goes into them. And although Browning anticipates some growth ahead for propylene oxide in making polyurethanes and surfactants, and for cumene as the precursor of phenol, he points out that these "account for a relatively small percentage of the propylene demand." Isopropyl alcohol use likely will remain flat for the next several years.

Overall, he expects that the West European chemical industry will require about 16.5 billion lb of propylene in 1990 compared with nearly 12.5 billion lb in 1980. That would represent a 2.9% annual growth in use—relatively high when compared with the anticipated yearly growth rate of 1.2% predicted for ethylene, and 1.6% for industrial output as a whole, during the 10-year period.

Browning sees a gap widening between the quantity of propylene coproduced in Western Europe's crackers and need for the olefin by the chemical industry there. "The prime purpose of steam crackers," as he points out, "is to make ethylene." The "quite good" capacity utilization of the cracker population likely will result in the crackers' declining ability to keep pace with increasing propylene demand, he reasons.

The type of feedstock used and the severity of the cracking operations also have a significant effect on the relative amount of propylene produced. At one time, naphtha was used almost exclusively in crackers throughout Europe. This feedstock gives rise to about a pound of propylene for every 2 lb of ethylene. But there is a trend to build flexibility into the crackers to allow use of such "lighter" feedstocks as liquefied petroleum gas and ethane, with a resulting drop in propylene output. Indeed, in the case of ethane, the level of propylene made is negligible.

Not only is a cracker's propylene output dependent on the type of feedstock used, but the conditions of operation is a factor. High temperatures favor ethylene formation; at lower temperatures, relatively more propylene is produced. Reducing the severity of the cracking could increase the amount of propylene available to West European chemical makers by up to 3.3 billion lb a year, Browning estimates. "In practice, however, some operators will not want to change," he believes.

European petrochemical compa-

nies in the market for propylene are benefiting from the move that is gaining momentum to reduce the amount of lead additives in gasoline for environmental reasons. As recently as two years ago, practically all the gasoline used throughout Western Europe contained 0.4 g per L of lead, mostly as tetraethyllead antiknock compound. Now, several countries have taken steps to reduce the lead in their gasoline pool. By 1990, only some 20% of West European gasoline is expected to remain leaded at the 0.4 g-per-L level. In 40%, it will be down to 0.15 g per L. The remaining 40% or so will be lead-free.

"To accommodate the removal of lead, the 'clear octane' value of the gasoline pool [the inherent octane rating of a fuel before blending in additives] must rise," he observes. "Fluidized catalytic crackers (FCCs) are playing an increasing role in helping refiners meet this demand."

One outcome of the move to fluid catalytic cracking is an increase in the relative abundance of propylene in the refinery streams. "The more FCCs become economically viable, the harder they will get driven to raise the octane number, and the more propylene will result," Browning says. "Additionally, the newer catalysts being employed in the FCCs favor propylene yield. The net effect of all this is that more propylene is being produced in European refineries, and there now is a steady increase in the amount being purified for chemical use."

Propylene demand isn't the prime driving force either of steam cracker operators or refinery managers. But because demand for propylene is growing faster than that for ethylene, it isn't surprising that on a long-term basis the ratio between propylene and ethylene prices is steadily rising, he reasons.

"From a level of around 40% of the ethylene price in 1970, propylene now commands a price of about 80% that of ethylene." Although this trend is a fairly steady transition over the past 15 years, the price relationship can undergo wide swings depending on such factors as the degree of demand, the amount of stocks on hand, oil and gas prices, and the like. □

Most propylene uses in Western Europe are growing

Millions of lb	1980	1985	1988*	1990*	Average annual growth	
					1980-85	1985-90
Polypropylene	3,366	5,390	5,786	6,600	9.9%	4.1%
Acrylonitrile	2,200	2,684	2,552	2,200	4.1	-3.9
Oxo-alcohols	2,178	1,980	1,958	1,826	-1.9	-1.6
Propylene oxide	1,386	1,694	1,628	1,738	4.1	0.5
Cumene	1,012	1,298	1,210	1,408	5.1	1.6
Isopropyl alcohol	858	1,012	1,012	1,034	3.4	0.4
Others	1,452	1,694	1,850	1,716	3.1	0.3
TOTAL	12,452	15,752	15,796	16,522	4.8%	1.0%

* Estimates. Source: Imperial Chemical Industries

Congress Approves 8% Increase for Major R&D Funding Agencies

Appropriation bill sets higher funding levels for most federal R&D agencies in fiscal 1987, with NASA and NIH scoring the biggest gains

Janice R. Long, C&EN Washington

Perhaps the most important legislative action taken during the last chaotic days before final adjournment of the 99th Congress was passage of H.J. Res. 738, which rolled into one huge bill the 13 regular appropriation bills that provide funding for all the government departments and agencies in fiscal 1987. Until Congress cleared that measure on Oct. 17, more than two weeks after the beginning of fiscal 1987, none of the federal R&D agencies knew how much money they actually would be able to spend. For some of those agencies, the continuing resolution contained more money for them than was approved earlier by either the House or the Senate. For others, the funding approved was lower.

Most of the agencies will receive more R&D funding this fiscal year than in fiscal 1986, with the total budget for major R&D agencies up 8% to \$53.4 billion. The two biggest gains are for the National Aeronautics & Space Administration, whose R&D budget is up 19% to \$3.13 billion, and the National Institutes of Health, whose R&D budget is up 20% to about \$6.0 billion. The Administration had wanted to cut NIH's total budget 9%, but Congress once again performed its annual rescue operation, approving more than either the House or the Senate had done in their appropriation bills. Within NIH's budget, funding for the National Institute

of Allergy & Infectious Diseases is up an astonishing 65% to \$546 million, primarily owing to its part of the \$248 million included in the bill for research on acquired immune deficiency syndrome (AIDS).

Overall, Congress expects the budget total for NIH to support at least 6100 new and competing research grants—a number that the Office of Management & Budget has been trying to reduce in recent years—and at least 10,500 trainees.

The Department of Defense's R&D budget, up 8% to \$37 billion, didn't fare so well percentagewise as those for NASA and NIH. Nor did it match the 22% increase to \$42 billion that the Administration was seeking. Nonetheless, it remains by far the largest single component of federal R&D funding. However, only 8% of that \$37 billion, or \$3 billion, will be spent on DOD's technology base—that is, basic research activities, which are funded at a level only 2% higher than last year

and which provide funds for DOD-sponsored university research. But funding for another DOD program that supports university-based research, the Strategic Defense Initiative, is up 18% to \$3.2 billion. The Administration had requested a 77% increase to \$4.8 billion.

Given DOD's increasing investment in university-based research, Congress has requested a report that explains in detail DOD's current peer-review process in a step-by-step fashion. It must describe participants in this process and how they are chosen, and analyze the potential for expanding the research base into geographic areas that now receive little defense-related university funding. The resolution also directs DOD to develop a five-year plan providing for sustained real growth in both the University Research Initiative and the armed services' university research programs.

The resolution also limits the testing of antisatellite weapons in space

In its final days, 99th Congress passes several major bills

The 99th Congress has passed into history. Its final days were chaotic with bills flying back and forth between the House and Senate during sessions that lasted far into the night. Out of that chaos emerged important pieces of legislation in addition to the large appropriations bill. These include:

- An omnibus antidrug bill that mandates stiff penalties for manufacture, distribution, or possession of so-called "designer drugs."
- An immigration reform bill that does not, as earlier versions did, impose new requirements on foreign students.
- A bill allowing exports of drugs that have not been approved for use in the U.S.

- Amendments to the Clean Water Act that set strict criteria and timetables for limiting discharges of toxic pollutants into waterways.

- An \$8.5 billion five-year reauthorization of the abandoned hazardous waste site cleanup program called Superfund.

- Legislation allowing those seeking liability insurance to establish on an interstate basis either a "risk retention group" to self-insure, or a group to purchase such insurance cooperatively.

- Fiscal 1987 authorization bills for the Department of Defense, National Aeronautics & Space Administration, National Bureau of Standards, and Patent & Trademark Office.

Funding for major R&D agencies rises about \$4 billion

\$ Millions	1987		1986	% change 1986-87
	Congressional appropriation	Administration request		
Defense	\$36,622.1	\$41,740.3	\$34,057.3	8%
Tactical programs	11,422.3	12,671.4	10,546.7	8
Strategic programs	8,352.9	9,429.5	7,796.9	7
Intelligence and communications	4,996.8	5,066.8	4,504.2	11
Advanced technology development	4,746.9	6,574.7	4,170.8	14
Defensewide mission support	3,766.6	4,413.0	3,780.9	—
Technology base	3,336.6	3,584.9	3,257.8	2
NIH	5,999.7	4,833.8	4,983.1	20
Cancer	1,402.8	1,158.1	1,176.6	19
Heart, Lung & Blood	930.1	785.7	810.8	18
General Medical Sciences	570.9	471.5	492.4	16
Allergy & Infectious Diseases	545.5	340.8	330.5	65
Diabetes & Digestive and Kidney Diseases	511.1	418.9	433.5	18
Neurological & Communicative	490.2	399.3	413.0	19
Child Health & Human Development	366.8	309.1	307.7	19
Eye	216.6	179.2	186.5	16
Environmental Health Sciences	209.3	188.0	188.9	11
Aging	176.9	145.8	142.6	24
Arthritis & Musculoskeletal and Skin Diseases	138.7	106.7	110.7	25
Dental research	117.9	96.5	98.1	20
Research resources	322.9	234.2	290.7	11
Energy	3,903.1	3,844.2	3,824.0	2
Energy supply R&D	1,644.4	1,677.0	1,658.1	- 1
Supporting research and technical analysis	524.0	618.6	487.7	7
Fusion	345.5	333.0	365.5	- 6
Nuclear R&D	327.5	330.9	375.7	-13
Environment	273.9	258.1	228.6	20
Solar	124.2	72.3	144.6	-14
Other	49.3	34.1	56.0	-12
Weapons R&D	1,103.1	1,239.9	1,015.4	9
General science and research	708.4	773.4	655.9	8
Fossil R&D	295.5	82.8	311.0	- 5
Conservation R&D	151.7	71.1	183.6	-17
NASA R&D	3,127.7	3,032.1	2,638.3	19
NSF	1,622.1	1,685.0	1,483.8	9
Research and related activities	1,406.1	1,479.0	1,294.1	9
Antarctic programs	117.0	117.0	110.0	6
Science education	99.0	89.0	84.7	17
Commerce	1,180.6	960.4	1,215.9	- 5
NOAA	1,038.6	836.5	1,097.2	- 5
NBS	122.0	123.0	118.7	3
USDA	966.6	870.9	885.7	9
Agricultural Research Service	537.1	513.0	484.1	11
Cooperative State Research Service	300.6	246.4	276.1	9
Forest Service research	128.9	111.5	125.5	3
EPA R&D	303.5	295.2	324.6	- 7
TOTAL	\$53,405.4	\$57,261.9	\$49,417.7	8%

Note: All figures are estimates. Source: Congressional budget documents

and the production of the Bigeye binary chemical bomb. No test of antisatellite weapons can be carried out until the President certifies that the Soviet Union has conducted, after the date the resolution was signed, a test of a dedicated antisatellite weapon against an object in space. The resolution also states that no funds may be obligated for procurement or assembly of the Bigeye bomb before Oct. 1, 1987.

The National Science Foundation was one agency that was hoping for more from the continuing resolution than it got. NSF wanted the resolution to go along with the Senate reversal of the House's decision to cut \$136 million from NSF's total budget request and \$146 million from the research and related-activities request. NSF had warned that if the House action was allowed to stand, it would result in the loss of some 1000 grants, eliminating support for about 1500 scientists and engineers. The continuing resolution, however, splits the difference between the House and Senate positions, giving NSF a 9% increase in its total budget to \$1.6 billion and also a 9% increase, not the requested 14%, in its research and related-activities budget to \$1.4 billion.

The funding measure also does not fully restore the \$5 million the House cut from the \$101 million budget request for the Department of Energy's chemical sciences program. Final funding for that program is set at just over \$98 million, a 6% increase over fiscal 1986 funding levels. Funding for DOE's materials science program is set at \$235 million, 25% over fiscal 1986 and 20% over the budget request, and includes \$4 million for the National Center for Chemical Research. DOE's overall R&D budget is up a slight 2% to \$3.9 billion.

Among other funding decisions are an 11% increase to \$537 million for the Agricultural Research Service and a 3% increase to \$122 million for the National Bureau of Standards. However, the budget for the National Oceanic & Atmospheric Administration's research activities is down 5% to \$1 billion, and the Environmental Protection Agency's R&D budget is down 7% to \$304 million. □

Concerns About World Oil Problems Are Growing

Institute of Gas Technology conference addresses negative impacts of oil price drop and its potential for causing future oil crises

Joseph Haggin, C&EN Chicago

The recent drop in crude oil prices has a down side that many people view as a crisis. Producing countries around the world have been hurt. And in the U.S., the price decline has had a severe economic impact on producing states and on the industry, while the country has increased its reliance on imports. Dealing effectively with the situation will require concerted government action, industry planning, honing national objectives, and international cooperation.

A growing consensus in the U.S. among those most directly affected, including the chemical and petrochemical industries, suggests that preventive measures must be taken soon to avoid panics such as those of 1973 and 1979. In the longer term, the course and character of chemical technology related to energy inevitably will be altered by the measures chosen. But steps taken now could allow that course and character to be determined by users rather than having them dictated from abroad.

That's the situation addressed last month at a conference on "Confronting the Crisis in World Oil" in Houston. The title is the general topic of a new series of symposia sponsored by the Institute of Gas Technology (IGT) and begun with the meeting in Houston.

A common theme in formal and informal discussions at the meeting

was that the Organization of Petroleum Exporting Countries may have done itself in with its activities during the past decade. OPEC may possibly display its former solidarity again, but even if it does, the nature of the oil business has changed permanently. Substitution of other fuels for oil, the emergence of C_1 chemistry as an industrial sector, conservation, and growing world reliance on nuclear power leave little doubt that the industrial countries will take pains to avoid another bout of market manipulations by OPEC like those of the 1970s.

The U.S. has been especially hard hit by recent oil-related events. Domestic production has suffered considerably in recent months, and it's feared that additions to reserves will not keep pace in the future because of the demise of the domestic drilling industry. Solutions to that situation depend in large part on the policies of the U.S. government, which, according to some in the oil industry, doesn't always pay enough attention to domestic problems.

The State Department, not surprisingly, considers the greatest problem in the oil business to be OPEC. Marion V. Creekmore, the department's deputy assistant secretary for Near Eastern and South Asian affairs, says the U.S. approach to OPEC has been consistent for a long time. The U.S. government believes, he says, that market forces, and not OPEC producers, should control oil markets and determine prices. The U.S. opposes OPEC and other cartels because they restrain trade.

As Creekmore notes, market forces began to be felt after 1980, despite the action of the cartel. One of the major results was a sharp increase in non-OPEC oil production. OPEC attempted to maintain high

U.S. imports of crude oil increase from last year's level

Thousands of barrels per day	First six months		Change
	1985	1986	
Field production	9,010	8,872	-138
Imports	2,988	3,600	612
Refinery inputs	11,729	12,497	768
Field production as % of refinery inputs	77%	71%	-6%
Imports as % of refinery inputs	25%	29%	4%

prices using production quotas, but revenue squeezes wouldn't permit output to be cut for very long. Saudi Arabia eventually abandoned its role as swing producer, and prices started to drop. OPEC is now trying to regroup and re-establish itself.

The distinction between radical and moderate states in the Persian Gulf region was repeatedly emphasized by Creekmore, who notes that the Gulf Cooperation Council (Saudi Arabia, Kuwait, Oman, the United Arab Emirates, Bahrain, and Qatar) is working toward economic and military integration. The U.S. supports these efforts, he says, and believes that a strong council will increase Middle East stability. That could be of crucial importance if the Iran-Iraq War is settled in favor of Iran in the next few months, as some believe it will be.

Another State Department official, Daniel P. Serwer, director of energy consumer country affairs, outlined the U.S. energy-policy response to falling oil prices. The changes were, he said, strictly responses to market pressures designed to remove "impediments to energy production." The lower oil prices have reduced OPEC's room for maneuvering and, generally, im-

proved the trade picture for most importers. This stimulated economic growth and could be particularly beneficial for countries such as Japan, West Germany, and Italy, where economic growth could be as much as 1% higher than for other members of the Organization for Economic Cooperation & Development (essentially the noncommunist, industrialized countries).

Things aren't quite so rosy in the U.S. Serwer notes that, contrary to expectations, low prices have had a pronounced negative effect on U.S. oil companies, even though the total economy may have benefited. The U.S. is still the world's second largest oil producer, and the economic problems are most severe in the producing states of Texas, Alaska, Oklahoma, and Louisiana. The U.S. is also the largest importer of oil. It cannot let lower prices reverse the positive effects of conservation, substitution, and indigenous production, or energy security will be reduced, Serwer points out. The State Department does not expect this to happen, he says.

However, the government's efforts to ensure energy security have been criticized. One of the most controversial issues has been oil import fees. The Reagan Administration has rejected such import fees on the grounds that they fall heaviest on low-income consumers, erode competitiveness, and cause more problems for heavily indebted exporting countries. The Administration is also accelerating the completion of the strategic petroleum reserve and encouraging allies to likewise build up reserves. But much of the reaction to what the Administration has done to counter the effects of falling prices can be summed up in the statement that it is too little and too late.

The extent of changes in the nature of the oil business was pointed out at the conference by Charles L. Campbell, retired senior vice president of Gulf Oil Corp. He noted that until 1975, more than 80% of the world's oil reserves were in the hands of eight international companies. In 1980, these same companies owned less than 10% of the reserves. In the same period, OPEC gained and then lost control of oil

pricing. Campbell maintains that price stability as once administered by the Texas Railroad Commission and the major international oil companies is no longer feasible. No entity now has either the discipline or the appropriate interests to regulate production.

Present excess world production capacity, Campbell explained, operates at low cash costs, and that makes it difficult to justify any new energy projects strictly on the basis of economics. Investment decisions will be made to purchase reserves, existing refineries, and existing market assets rather than to build new facilities or expend risk capital on frontier exploration. So far, the changes in the oil industry have been the result of political or military action, and that pattern is likely to continue, with more nations involved in the total struggle for dominance.

The key historical fact, Campbell says, is that oil is now a commodity. Prices will continue to cycle rapidly with random volatility. Business structures will change from the traditional organization by function to a highly centralized management with few levels, small staffs, and hands-on control by managers with high-capacity personal computers networking with massive databases.

Another gloomy picture was offered by William Johnson, president of Joffe Corp. and former chief economist with Tenneco Inc. Most of the oil industry's problems Johnson traces to OPEC's gyrations. He is skeptical about whether OPEC "can get its act together." Even if it does, he says, it probably will find that raising prices much above \$20 per barrel would not benefit its long-term interests.

Some individuals and groups in the oil industry are saying that the U.S. is facing an inevitable national catastrophe. Currently, consumers are trading short-term price benefits for long-term security without even realizing that the trade is being made. Johnson questions that forecast, but he admits that there is reason for concern over future crises. The problem is the fear of shortages, and that, Johnson says, is the catalyst for another crisis.

Contrary to the opinion of many,

Johnson maintains that U.S. supply security is still an issue. The Saudis are no longer functioning as the balance wheel in OPEC production. The Saudis are now in a full-scale oil price war with the other producers.

Johnson suggests that it may be wishful thinking to believe the U.S. is now in a better position to cope with another crisis. It is true that it is somewhat better insulated against politically inspired limitations on production or price increases. Natural gas access is better, and nuclear power is developing, if slower than many would like. Interfuel competition is greater than ever before and growing. However, it is not certain, he says, that these measures would safeguard the country from another "oil bumble."

It is not where the U.S. is but where it is going that should arouse concern, Johnson says. The decline in drilling activity is a severe problem. Current reserve additions are down to 30% for 1986, and domestic reserves won't support present production levels very long. The only option after current reserves are depleted will be more imports, and the U.S. will be right back where it started in the 1970s.

With most attention being given to Middle East/European/North American oil problems, many observers fail to notice that future oil markets will be oriented increasingly in the Pacific. With the exception of Japan, Singapore, and Taiwan, most of the Pacific countries are developing, and the stakes for them are large indeed. Just how large was examined by Eugene D. McCarthy, division chief in the energy department at the World Bank. In the region are three significant oil-exporting countries—Indonesia, Malaysia, and China—and three significant oil-importing countries—South Korea, the Philippines, and Thailand. The exporters are expected to suffer from low prices and the importers to benefit. However, the simultaneous decline of the dollar will have adverse effects all around, with Japan probably affected most.

In contrast, OECD countries have been the chief beneficiaries of the price collapse, with Japan, West Germany, France, and Italy receiving about 40% of the total benefit. □

NOVEMBER 10, 1988

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CHEMICAL & ENGINEERING

NEWS

Chemical Earnings

The climb continues
in third quarter

Page 10

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News of the Week

■ **Merger of West Germany's Hoechst with Celanese will create the world's largest chemical firm.** **Page 4**

■ **Gordon L. Nelson, chairman of the department of polymer science at the University of Southern Mississippi, has been elected ACS's 1987 president-elect.** **Page 5**

■ **Chemistry Day programs have been scheduled by several ACS local sections this fall, which will serve as trial runs for the 1987 National Chemistry Day.** **Page 6**

Government

Rep. Don Fuqua, retiring from the House, makes recommendations to improve the science infrastructure, based on two-year task force study on how science policy is set and how it works. **Page 16**

Science

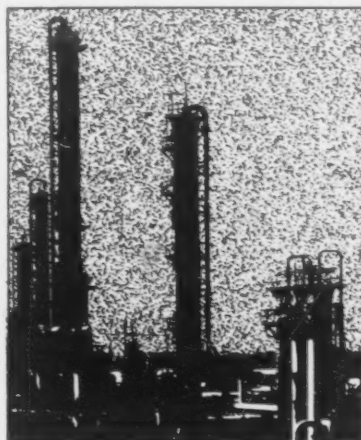
Sigma Xi celebrates its centennial by focusing on expanding its international activities, developing science-and-society programs, and dealing with current problems of U.S. science. **Page 20**

Max Tishler, noted chemist and former ACS president, is feted by 300 friends, colleagues, and students on Wesleyan University's campus on the occasion of his 80th birthday. **Page 22**

ACS News

The society commends OSHA on several aspects of its proposed standards for laboratory workers, but says some requirements need to be strengthened. **Page 27**

Letters	2
Concentrates	
Business	7
Government	15
Science/Technology	18
The Departments	
ACS Comment	24
Newsclips	40



Business

Chemical earnings continue to climb in third quarter, as a result of ongoing streamlining of companies, falling value of dollar against foreign currencies, and lower oil and natural gas prices. **Page 10**

Chemical Earnings Continue To Climb in Third Quarter

William J. Storck, C&EN New York

Earnings for major chemical companies continued to increase in the third quarter, spurred once again by improved utilization of plant and personnel and increased production. Earnings at major diversified companies that produce chemicals also were up, but earnings at petroleum and natural gas-producing firms were down because of the drop in oil price and excess supplies.

For the July-to-September peri-

od, combined earnings for the 30 largest chemical companies, excluding any significant nonrecurring and extraordinary items, climbed 23% to about \$757 million. Sales totaled \$16.8 billion, essentially the same as in third-quarter 1985. As a result, profit margins (earnings as a percentage of sales) for the 30 companies rose to an average of 4.5% from an average of 3.7% in last year's third quarter.

The year-to-year comparison may not be so rosy as it seems, however,

since last year's third quarter was a very poor one—the next to last quarter before the chemical industry began its earnings turnaround at the beginning of 1986. In fact, the third quarter's 4.5% profit margin for the 30 firms is less than in either this year's first quarter (4.8%) or second quarter (5.6%).

The major spur to increased earnings in three successive quarters of 1986 seems to be the streamlining that companies have been performing over the past few years. These

Chemical industry leaders for the third quarter . . .

Sales			Earnings ^a			Profitability		
Rank 1986	\$ Millions	Rank 1985	\$ Millions	Rank 1985		Earnings as % of sales	Rank 1985	
1 Dow Chemical	\$2787.0	1	Dow Chemical	\$170.0	1	International Flavors	13.7%	1
2 Monsanto	1695.0	2	PPG Industries	82.5	2	Ethyl	11.6	4
3 Union Carbide	1552.0	3	Hercules	53.1	7	Loctite	8.6	6
4 W. R. Grace	1321.2	4	Celanese	50.0	3	Hercules	8.3	12
5 PPG Industries	1140.0	5	Ethyl	46.8	5	Nalco Chemical	8.1	3
6 American Cyanamid	921.4	6	American Cyanamid	44.8	9	Rohm & Haas	7.6	7
7 Chesebrough-Pond's	733.4	9	Chesebrough-Pond's	40.4	12	Lubrizol	7.6	11
8 Celanese	693.0	8	Union Carbide	38.0	11	PPG Industries	7.2	9
9 Hercules	638.7	10	Rohm & Haas	37.3	6	Celanese	7.2	10
10 B. F. Goodrich	574.1	7	Air Products	33.4	4	Air Products	6.6	5

. . . and for the first nine months of 1986

Sales			Earnings ^a			Profitability		
Rank 1986	\$ Millions	Rank 1985	\$ Millions	Rank 1985		Earnings as % of sales	Rank 1985	
1 Dow Chemical	\$8543.0	1	Dow Chemical	\$572.0	1	International Flavors	14.5%	1
2 Monsanto	5309.0	2	Monsanto	278.0	3	Ethyl	10.4	5
3 Union Carbide	4649.0	3	PPG Industries	243.5	2	Freeport-McMoRan	10.1	2
4 W. R. Grace	3982.2	4	Hercules	176.3	8	Loctite	9.0	4
5 PPG Industries	3490.0	5	Celanese	156.0	5	Hercules	8.9	12
6 American Cyanamid	2866.3	6	American Cyanamid	150.4	9	Rohm & Haas	8.2	9
7 Chesebrough-Pond's	2341.0	10	Union Carbide	133.0	4	Nalco Chemical	7.9	3
8 Celanese	2183.0	9	Rohm & Haas	131.4	6	Celanese	7.1	13
9 B. F. Goodrich	2062.0	7	Chesebrough-Pond's	125.9	14	Lubrizol	7.0	10
10 Hercules	1975.0	9	Ethyl	124.0	10	Air Products	7.0	7
						PPG Industries	7.0	8

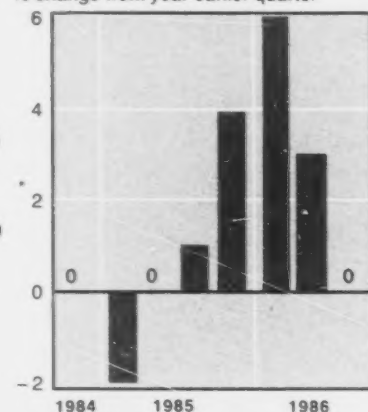
^a After taxes. Note: For 30 chemical companies listed on page 12.

Chemical industry 1986 third-quarter results

- Sales were unchanged
- Earnings climbed 23%
- Profit margins fell to 4.5%
- Production rose 5.5%
- Prices declined almost 2%

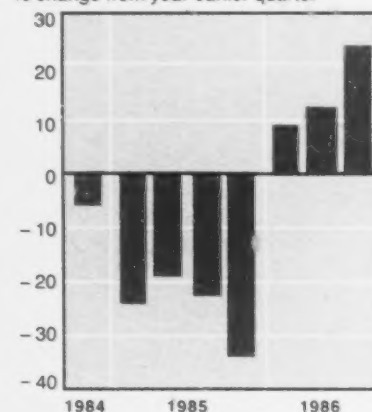
Sales

% change from year-earlier quarter



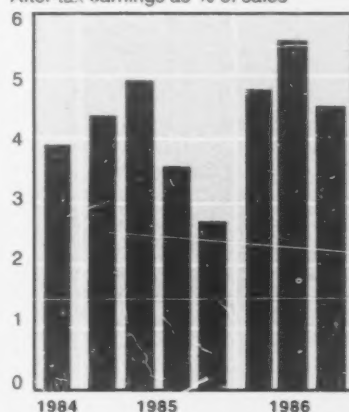
Earnings

% change from year-earlier quarter



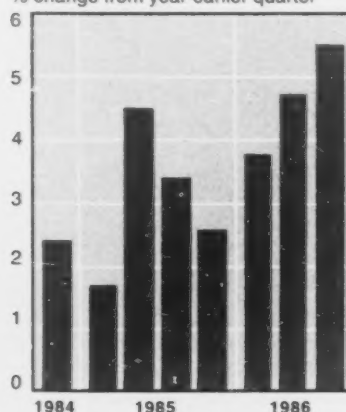
Profit margins

After-tax earnings as % of sales



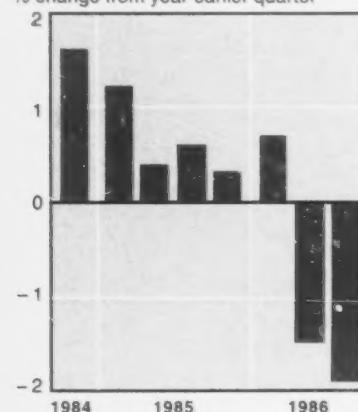
Production

% change from year-earlier quarter



Prices

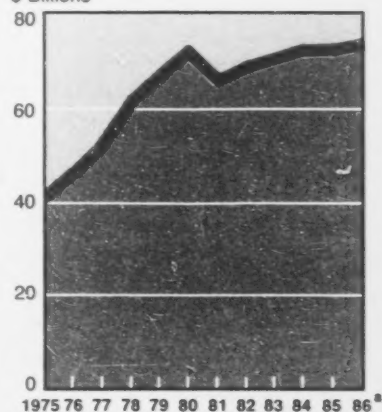
% change from year-earlier quarter



Sales in 1986 will be up slightly, and earnings will climb about 20%, increasing profit margins to about 5.3%

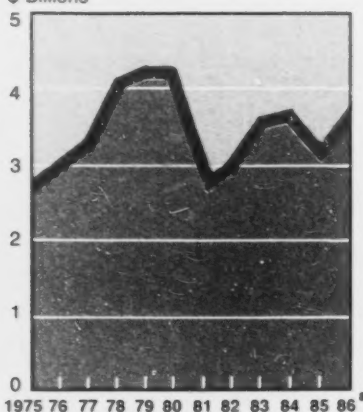
Annual sales

\$ Billions



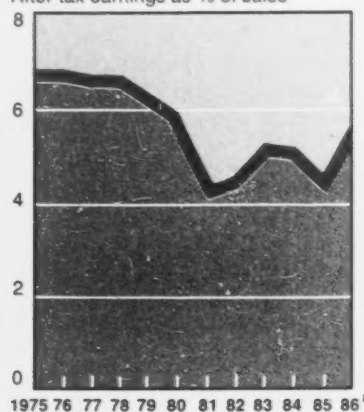
Annual earnings

\$ Billions



Annual profit margins

After-tax earnings as % of sales



■ C&EN estimates. Note: All sales, earnings, and profit-margin data are based on combined results of 30 companies listed on page 12.

Earnings, profit margins up substantially for most chemical firms in third quarter

	THIRD-QUARTER 1986						NINE-MONTHS 1986			
	Sales	Earnings ^a	Change from 1985		Profit margin ^b		Sales	Earnings ^a	Change from 1985	
	(\$ millions)		Sales	Earnings	1986	1985	(\$ millions)		Sales	Earnings
Air Products ^c	\$ 502.5	\$ 33.4	5%	-12%	6.6%	8.0%	\$ 1,506.3	\$ 105.2	8%	-6%
American Cyanamid ^c	921.4	44.8	8	52	4.9	3.5	2,866.3	150.4	8	44
Celanese ^c	693.0	50.0	-9	6	7.2	6.2	2,183.0	156.0	-5	22
Chemed	108.8	5.0	12	-4	4.6	5.4	306.5	15.5	10	-11
Chesebrough-Pond's ^c	733.4	40.4	5	104	5.5	2.8	2,341.0	125.9	25	135
Crompton & Knowles	59.3	1.9	5	8	3.2	3.1	186.0	6.4	7	23
Dow Chemical ^c	2,787.0	170.0	-3	59	6.1	3.7	8,543.0	572.0	-1	54
Essex Chemical	48.0	1.6	4	9	3.3	3.1	159.4	8.0	6	9
Ethyl ^c	404.9	46.8	5	33	11.6	9.1	1,188.9	124.0	2	25
First Mississippi	55.2	-0.1	-16	def	def	def	184.9	4.0	-11	-57
Freeport-McMoRan	132.1	7.6	-18	-58	5.7	11.0	458.1	46.1	-19	-27
H. B. Fuller	136.6	5.7	17	47	4.2	3.3	388.6	13.8	14	51
B. F. Goodrich ^c	574.1	13.7	-31	1613	2.4	0.1	2,062.0	0.2	-15	-99
W. R. Grace ^c	1,321.2	4.3	6	-84	0.3	2.2	3,982.2	4.7	5	-93
Hercules ^c	638.7	53.1	4	59	8.3	5.4	1,975.0	176.3	1	59
International Flavors	164.9	22.5	29	24	13.7	14.3	475.0	68.7	25	25
International Minerals	340.3	-6.7	55	def	def	0.0	1,190.9	-26.9	23	def
Loctite	70.7	6.1	16	29	8.6	7.8	211.5	19.0	21	13
Lubrizol	232.8	17.7	15	54	7.6	5.7	770.2	54.1	9	16
Monsanto ^c	1,695.0	13.0	-3	-58	0.8	1.8	5,309.0	278.0	6	15
Nalco Chemical	184.5	15.0	10	-12	8.1	10.1	547.0	43.0	10	-13
National Distillers ^c	541.6	10.1	-3	-44	1.9	3.2	1,703.9	42.3	4	-1
Olin ^c	407.5	7.0	-5	27	1.7	1.3	1,300.0	56.4	-4	80
Pennwalt	272.2	14.0	10	def	5.1	def	828.6	39.4	9	692
Petrolite	63.6	2.3	-14	-55	3.6	6.9	214.0	13.9	-6	-26
PPG Industries ^c	1,140.0	82.5	5	12	7.2	6.8	3,490.0	243.5	7	0
Reichhold Chemicals	178.5	2.5	-14	def	1.4	def	600.9	6.5	-4	56
Rohm & Haas ^c	488.5	37.3	3	7	7.6	7.3	1,598.3	131.4	1	13
Union Carbide ^c	1,552.0	38.0	2	46	2.4	1.7	4,649.0	133.0	0	-2
Witco	337.9	17.2	-8	8	5.1	4.4	1,028.9	48.7	-7	17
Total 15 largest companies ^d	\$14,400.8	\$644.4	-1%	22%	4.5%	3.6%	\$44,697.8	\$2299.3	2%	20%
Second 15 companies	\$ 2,385.6	\$112.2	8%	28%	4.7%	3.9%	\$ 7,550.7	\$ 360.3	5%	-8%
GRAND TOTAL ^d	\$16,786.4	\$756.7	0%	23%	4.5%	3.7%	\$52,248.5	\$2659.6	3%	15%

^a Earnings from continuing operations, excluding significant nonrecurring and extraordinary items. ^b Earnings as a percentage of sales. ^c One of 15 largest companies. ^d Dow Chemical results are not included in 12-month running totals because of large pretax nonrecurring loss in the fourth quarter of 1985. **def** = deficit.

actions have served to lower effective breakeven points at most firms so that a slight increase in production causes a more than arithmetic increase in earnings and, therefore, margins. Also, companies are benefiting from an improved international situation. The falling value of the dollar against foreign currencies has helped increase exports for some companies, while serving to decrease competition in the U.S. from foreign goods, by increasing their effective price. The fall of the dollar has helped in many areas, but unfortunately not in Canada—the U.S.'s largest trading partner—

nor in South Korea, where currencies also have fallen in value along with the dollar.

Other benefits have resulted from lower prices for oil and natural gas, which translates to lower raw material costs for production of petrochemicals, by far the largest segment of the U.S. chemical industry.

One area not contributing generally to the chemical industry's strong performance is product pricing. In the third quarter, prices for chemicals and allied products, according to Department of Labor statistics, declined almost 2% from third-quarter 1985. In the second quarter,

prices were down 1.5% from a year earlier. Essentially two factors account for the price decline—overcapacity and pressure from customers because of the falling oil price. The chemical industry, according to government estimates, is still operating at about 80% of capacity, although plants for some products are operating at much higher rates than that. But operating rates in the 80% range still do not allow for much in the way of price increases. The pricing problem is exacerbated in petrochemicals by the declining oil price and customer demands that petrochemical suppliers make their

NINE-MONTHS 1986

Profit margin^b

1986 1985

12-MONTH RUNNING DATA

Change from 1985

Profit margin^b

Sales Earnings

1986 1985

7.0%	8.0%	8%	-3%	7.0%	7.8%
5.2	3.9	2	19	5.0	4.3
7.1	5.6	-5	29	7.0	5.1
5.1	6.3	9	8	4.6	4.6
5.4	2.9	29	123	4.4	2.5
3.5	3.0	7	21	3.6	3.2
6.7	4.3	1	-41	2.3	3.9
5.0	4.9	6	-10	4.6	5.4
10.4	8.5	1	18	10.3	8.9
2.2	4.5	-5	-50	2.8	5.2
10.1	11.1	-22	-35	9.8	11.7
3.5	2.7	12	43	3.6	2.8
0.1	2.2	-12	-160	-0.3	0.4
0.1	1.8	-9	-60	0.8	1.9
8.9	5.7	2	26	7.3	5.8
14.5	14.5	24	23	13.9	14.0
def	4.3	14	-138	-1.5	4.6
9.0	9.7	19	10	8.9	9.6
7.0	6.6	8	7	6.8	6.9
5.2	4.8	8	-22	3.1	4.3
7.9	9.9	10	-11	8.6	10.6
2.5	2.6	6	9	2.5	2.4
4.3	2.3	-12	18	3.3	2.4
4.8	0.7	4	106	4.1	2.1
6.5	8.2	-3	-32	5.9	8.5
7.0	7.5	7	-4	6.6	7.3
1.1	0.7	-1	-143	-0.6	1.3
8.2	7.4	2	10	7.5	7.0
2.9	2.9	-13	-35	2.1	2.9
4.7	3.8	-7	14	4.6	3.8
5.1%	4.4%	-1%	-1%	4.0%	4.0%
4.8%	5.5%	4%	-17%	4.6%	5.8%
5.1%	4.5%	0%	-4%	4.1%	4.3%

own prices reflect any breaks they get on raw material costs.

Production, however, is increasing. In the third quarter, output was about 5.5% higher than in third-quarter 1985, following a 4.7% year-to-year rise in the second quarter.

With a combination like that, chemical companies have to rely on the improved earnings leverage brought about by the cuts in personnel, the streamlining of plants, and the pruning of unprofitable or marginally profitable lines of business that have been taking place for the past few years.

As the third-quarter results attest,

those moves are working. Earnings improvements in the quarter came from many segments of the chemical economy, with the exception of fertilizers. For Dow Chemical, executive vice president Robert M. Keil says: "All of Dow's business segments posted improved operating income over the comparable period of 1985, and we continued to operate our plants at high rates in our basic chemicals and basic plastics segments. Further tightening in supply and demand balances for basics is helping support the earnings capability of these businesses in this period of lower costs for some raw materials, particularly hydrocarbons."

At Du Pont, the country's largest chemical producer, chairman Richard E. Heckert says, "Results for the third quarter are encouraging. Most of our chemical and specialty products businesses posted strong results, reflecting our improved cost structure and strength overseas."

Even agricultural chemicals, with the exception of fertilizers, seemed to be improving in spite of the bad farm economy. George J. Sella Jr., chairman of American Cyana-

mid, remarks that worldwide sales of the company's agricultural chemicals group were about even in the third quarter with those of the previous year, despite the company's withdrawal from the diammonium phosphate business in June.

Rohm & Haas chairman Vincent L. Gregory Jr. says: "The agricultural business outside the U.S. was strong, and we continue to see market penetration and volume growth for new products." But he adds, "The depressed condition of the U.S. farm economy, combined with increased competition, led to lower sales of Blazer, our soybean herbicide."

Ground rules for C&EN earnings analysis

C&EN's quarterly report on financial performance of the U.S. chemical industry contains data from the 30 largest U.S. basic chemical companies and from 34 oil and diversified companies, each with more than \$200 million in annual chemical sales.

To be included in the table of basic chemical producers, a company must have at least 40% of its sales in chemicals, and its chemical operations must be the largest single portion of the total operations. That is why Du Pont, for example, is included in the table of diversified manufacturers.

In referring to chemical sales, C&EN means those chemicals whose molecular composition has been changed in the course of manufacture. Hence, chemical sales include those of traditional categories of basic petrochemicals and inorganics, organic intermediates and inorganic compounds, polymers, agricultural chemicals, and specialty derivatives.

In listing earnings, the survey gives after-tax income for continuing operations before nonrecurring items and extraordinary charges. Foreign currency translations are included.

Fertilizers, however, still are suffering. For instance, W. R. Grace & Co. says it had an \$8.6 million loss in the third quarter on fertilizer operations. And First Mississippi says it had a \$700,000 pretax loss on fertilizer, compared with a \$300,000 loss on those operations in the same period last year.

In the third quarter, the industry returned to a long-term pattern of the smaller, more specialty-oriented firms outperforming the larger, more commodity-oriented firms. This trend had been suspended in the past few quarters as the smaller firms had been hit by higher costs and more limited market growth.

In this year's third quarter, the smaller 15 firms of the 30 firms surveyed posted a combined earnings gain of 28% to \$112 million on a sales increase of 8% to \$2.39 billion. The group's average profit margin for the quarter was 4.7%, compared with 3.9% in third-quarter 1985.

Earnings were down for most oil firms, but up for diversified

	% chemical sales	THIRD-QUARTER 1986						NINE-MONTHS 1986					
		Sales	Earnings ^a	Change from 1985		Profit margin ^b		Sales	Earnings ^a	Change from 1985		Profit margin ^b	
		(\$ millions)		Sales	Earnings	1986	1985	(\$ millions)		Sales	Earnings	1986	1985
OIL AND GAS COMPANIES													
American Petrofina	15%	\$ 509.6	\$ 5.7	-15%	-47%	1.1%	1.8%	\$ 1,493.0	\$ -29.6	-15%	def	def	1.7%
Ashland	18	1,700.0	45.0	-23	-2	2.6	2.1	5,300.0	164.0	-13	37	3.1	2.0
Atlantic Richfield	17	3,532.0	121.0	-36	-70	3.4	7.3	11,368.0	570.0	-33	-51	5.0	6.8
Chevron	6	6,000.0	208.0	-42	-15	3.5	2.4	21,700.0	801.0	-37	-15	3.7	2.7
Exxon	12	17,186.0	1075.0	-23	-11	6.3	5.4	57,410.0	4149.0	-16	10	7.2	5.5
Kerr-McGee	14	601.2	-10.8	-24	def	def	5.0	1,945.8	14.5	-20	-87	0.7	4.5
Mobil	5	11,180.0	332.0	-24	-15	3.0	2.7	37,233.0	1354.0	-15	21	3.6	2.5
Occidental Petroleum	10	3,717.2	39.1	10	-81	1.1	5.9	11,175.2	152.0	4	-64	1.4	3.9
Phillips Petroleum	15	2,190.0	-23.0	-44	def	def	3.0	7,640.0	120.0	-36	-66	1.6	2.9
Shell Oil	19	4,011.0	133.0	-22	-64	3.3	7.1	12,841.0	628.0	-14	-37	4.9	6.7
Standard Oil	4	2,239.0	52.0	-35	-85	2.3	10.1	7,750.0	428.0	-23	-60	5.5	10.7
Texaco	3	7,300.0	162.0	-35	-46	1.8	2.7	24,800.0	675.0	-29	-27	2.7	2.6
Unocal	11	1,914.0	21.8	-37	-68	1.1	2.2	6,296.9	126.6	-28	-66	2.0	4.2
Williams Cos.	24	425.0	-30.3	-23	def	def	def	1,728.4	-7.4	-26	def	def	0.9
DIVERSIFIED COMPANIES													
Allied-Signal	24	2,907.0	164.0	8	7	5.6	5.8%	8,759.0	536.0	3	5	6.1	5.6
Borden	33	1,270.0	65.9	6	28	5.2	4.3	3,650.0	154.5	5	17	4.2	3.8
Borg-Warner	28	881.5	53.2	8	0	6.0	6.5	2,710.4	153.6	10	33	5.7	4.7
Cabot	51	303.2	12.9	-13	37	4.3	2.7	953.5	43.7	-8	-1	4.6	4.3
Du Pont	45	6,393.0	322.0	-12	59	5.0	2.8	20,471.0	1182.0	-6	25	5.8	4.3
Eli Lilly	22	883.4	135.6	12	11	15.3	15.5	2,751.0	433.9	12	10	15.8	16.0
Emhart	15	472.6	18.8	12	3	4.0	4.3	1,510.1	56.6	17	20	3.7	3.6
Engelhard	26	568.3	12.1	7	28	2.1	1.8	1,587.4	39.0	0	24	2.5	2.0
FMC	50	664.9	26.8	-13	-55	4.0	7.7	2,224.6	101.7	-7	-35	4.6	6.5
GAF	46	197.2	24.5	2	57	12.4	8.0	571.5	61.6	2	46	10.8	7.6
General Electric	8	9,280.0	604.0	42	5	6.5	8.8	22,940.0	1762.0	17	5	7.7	8.6
Kaiser Aluminum	13	592.0	-2.2	12	def	def	def	1,676.9	-24.6	11	def	def	def
Koppers	44	438.8	30.6	7	4	7.0	7.2	1,066.7	47.8	2	962	4.5	0.4
Merck	13	1,053.7	173.0	23	27	16.4	15.9	2,979.8	503.9	15	24	16.9	15.7
JM	15	2,236.0	215.0	11	24	9.6	8.6	6,490.0	594.0	10	15	9.2	8.8
Morton Thiokol	38	449.3	33.1	-2	-5	7.4	7.5	1,454.3	99.2	3	5	6.8	6.7
Pfizer	10	1,163.1	176.6	15	14	15.2	15.4	3,313.1	501.6	12	14	15.1	14.8
Tyler	41	245.9	3.9	5	-34	1.6	2.5	724.4	11.8	4	-19	1.6	2.1
USX	6	3,300.0	-183.0	-38	def	def	2.7	12,168.0	-426.0	-23	def	def	2.6
Vulcan Materials	25	263.7	35.7	-3	14	13.5	11.5	720.8	74.3	-2	14	10.3	8.9

a From continuing operations excluding significant nonrecurring and extraordinary items. b Earnings as a percentage of sales. def = deficit.

The 15 larger firms registered a combined increase in earnings of 22% to \$644 million, but a 1% decrease in sales to a total of \$14.4 billion. Profit margins for the 15 larger firms rose to an average 4.5% from 3.6% in last year's third quarter.

The third quarter has done a lot to help out the industry's performance so far this year, showing a better average year-to-year gain than either of the other two quarters. Combined earnings for the same 30 firms in the second quarter were up 12% on a year-to-year basis, following a 9% rise in the first quarter.

For the first nine months this year, sales for the 30 companies increased an average of 3% to a total of \$52.2 billion. Earnings for the same companies climbed an average 15% to a total of \$2.66 billion. Profit margins rose to an average 5.1% from 4.5% in the same period last year.

For the first nine months, the larger firms had better earnings growth than the smaller ones. Earnings for the 15 larger firms increased an average of 20% to about \$2.30 billion on a 2% sales rise to \$41.7 billion. Meanwhile, earnings at the smaller companies declined 8%, primarily on the results of fertilizer compa-

nies, to \$360 million. Sales at these firms, however, rose a faster 5% to \$7.55 billion.

Profit margins for the larger firms rose to an average of 5.1% from 4.4% in the first nine months of 1985. Profit margins for the smaller chemical companies declined to an average of 4.8% from 5.5% in the comparable period last year.

For the 12 months ending with the third quarter, profitability for the 30 companies was down, falling to an average of 4.1% from 4.3%. For the larger firms, it was flat at 4.0%, but for the smaller companies, it fell to 4.6% from 5.8%. □

Synthetic fibers holding up well,
despite earlier forecasts
A Key Polymers Review Page 9

NOVEMBER 17, 1986

11/18/86
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Democrats
take control
of Senate
Page 22

News of the Week

■ **Accidental release of toxic chemicals into Rhine River causes public outcry.** Page 4

■ **Montedison, Italy's second largest firm, seeks to create a European Institute of Technology to foster international cooperation.** Page 5

■ **Public perception of contributions of engineering and technology is focus of two studies.** Page 5

■ **Union Carbide to sell and lease back its headquarters building and sell its electrical carbon business.** Page 5

■ **Although Clean Water Act has been pocket-vetoed by President Reagan, members of Congress vow to reintroduce bill.** Page 6

■ **EPA rules prohibiting land disposal of wastes containing dioxin and 21 solvents take effect.** Page 6

Letters	2
Editor's Page	3

Concentrates

Business	7
Government	20
Science/Technology	32

The Departments

New Products	48
ACS Comment	49
ACS Focus	50
Meetings	53
Newsclips	68

Business

Restraints on imported apparel and increase in consumer buying lift U.S. production of major synthetic fibers. Page 9

International Business

Mexico's petrochemical industry looks to future with optimism as the government makes changes to help make it a major exporter. Page 14

Science

Center for Catalysis & Surface Science at Northwestern encourages interdisciplinary approach to solve complex problems. Page 33

Chemists use exotic, short-lived organic radicals to test accuracy of theoretical picture of chemical bonding. Page 34

Technology

Japanese work on advanced materials is outpacing U.S. efforts, in line with aim for world dominance by the 1990s. Page 35

Books

The Bhopal disaster is the focus of two books that take a critical view of Union Carbide's attempts to resolve the legal issues. Page 39



Government

Now that the Democrats have gained a 10-seat majority in the Senate, items on the Democratic agenda are expected to receive more attention. Page 22

Restraints on Imported Apparel Lift Synthetic Fiber Output

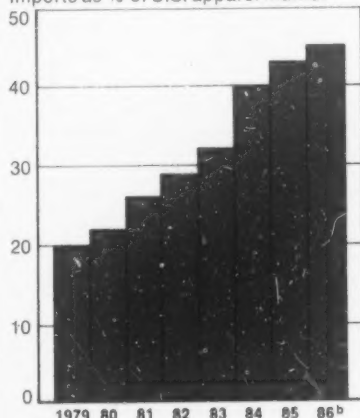
Imports curbs, rising demand likely will end production declines for polyester and fibers this year; nylon fiber output to surpass 1985 level

Bruce F. Greek, C&EN Houston

Throughout the U.S. textile industry, and in particular the synthetic fiber segment, producers are beginning to achieve some success in opposing imports of apparel that have devastated the industry during the past decade. Because of stringent curbs on imported apparel and a rise in consumer buying, 1986 U.S. production of major synthetic fibers will come close to matching, if not exceeding, last year's output. Nylon fiber output likely will surpass that of 1985. If output of polyester and acrylic fibers fails to beat last year's, the decline will be 1% or less.

Imported apparel takes rising share of U.S. market

Imports as % of U.S. apparel market^a



^a Per cent of total fiber weight. ^b C&EN estimate. Source: Man-Made Fiber Institute

Nevertheless, a return to production volumes of the 1970s for the synthetic fibers could be some time in coming. Production in 1986 will be more than 20% below levels of the late 1970s and, with optimistic growth forecasts of 1 to 2% annually, previous production totals will not be matched until well into the 1990s. Because of capacity shut-downs and high capital costs for synthetic fiber plants, production

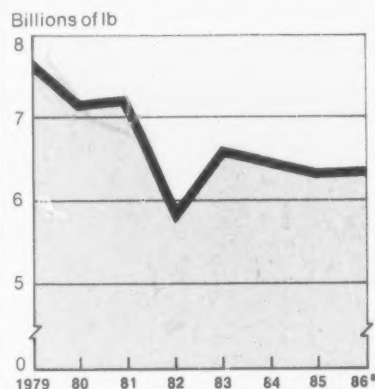
Key Polymers

may never match the previous levels for some fibers.

Because labor costs are lower in Pacific Rim countries, vast increases in imported apparel from them have resulted in declines in apparel manufacture and, thus, in synthetic fiber produced in the U.S. during the 1980s. The gap in labor costs may be closing because wage and benefit costs in the various Asian countries are increasing while those same costs in the U.S. garment industry are declining as a result of capital investment in new technology. Early in the 1980s, fiber exports rose to fill demands for textile manufacture in the garment-making countries. More recently, exports have declined as local fiber manufacture has developed to fill most needs in that area of Asia. Longer term, U.S. fiber production may get some pressure, as the net of exports over imports reverses unless constraints are put on fiber imports in addition to those on garment imports.

Yet, imports of apparel can be combated economically, according to industry sources. The long lead times required between orders for foreign-made garments and deliv-

Output of major synthetic fibers turns up slightly



Note: Excludes cellulosic and olefin fibers. ^a C&EN estimate. Source: Textile Economics Bureau

ery increases the risk of losing consumer acceptance and, if garments rapidly fade from fashion, then high markdowns needed to move the apparel can reduce or end profits. A U.S. program for responding quickly to retailers' wants has developed over the past two years throughout the manufacturing chain—from fiber makers through textile mills and mill suppliers to garment makers. Retailers currently can get delivery within two months of orders placed in the U.S. in contrast to a minimum of six months (and a more usual eight months) from foreign sources.

Through this quick response program, the "buy American" program, and because of quotas set by the various multifiber agreements, the growth rate of imported apparel this year has slowed. Those efforts have accounted in part for the improvement in synthetic fiber production.

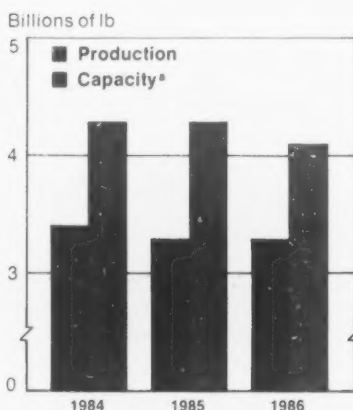
For details of the near-term outlook for polyester, nylon, and acrylic fibers, please see the following pages.

Key Polymers

Polyesters

- **Output off a bit**
- **Capacity excessive**
- **Prices pressured**

PRODUCTION/CAPACITY



MAJOR PRODUCERS

Allied-Signal, American Hoechst, BASF, Celanese, Du Pont, Eastman Chemical

HOW MADE

Ethylene glycol and dimethyl terephthalate or terephthalic acid reacted to make bis(2-hydroxyethyl) terephthalate (methanol as coproduct if using DMT), which is condensed catalytically to poly(ethylene terephthalate) and coproduct ethylene glycol

MAJOR END USES

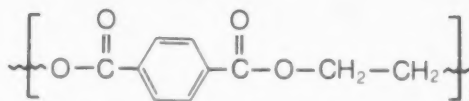
Apparel 50%, home furnishings 20%, industrial 30%

FOREIGN TRADE

Exports—expected to fall to about 200 million lb, imports—to rise to about 90 million lb

PRICES

Round 150-denier yarn 80 cents per lb, staple 70 cents per lb



Poly(ethylene terephthalate)

Polyester fiber output will be down again in 1986, primarily as a result of ever-higher imports of apparel containing these fibers. The decline, however, will be less than that of the past two years. Meanwhile, plant capacity has declined more than production, thereby raising the average operating rate. Polyester fiber production this year also will be affected by other, diverse factors, such as lowered cotton prices, declining fiber exports, and rising fiber imports.

Drops in volume of polyester fiber output have become smaller in recent years. For example, production in 1986 is now forecast to decrease as little as 20 million lb, to 3.32 billion lb, or less than 1%. This year's decline, if it does occur, will follow a 1985 decline of about 50 million lb, to 3.34 billion lb, or 1.5%. Production ranging from 3.3 billion to 3.4 billion lb is down significantly from the peak years of 1979 and 1981 when it was almost 4.18 billion lb.

Capacity to make polyester fibers has slipped to about 4.1 billion lb. Actual operable capacity varies with the size (denier) of fiber being produced and with the time of the year. On the basis of a nominal 4.1 billion lb of capacity and a 1986 output of 3.3 billion lb, the average operating rate will be about 80%. This rate is up from 77% in 1985.

Even with declines in production during the past five years, polyester fiber remains the largest volume fiber consumed in U.S. textile mills. For the past 10 years, it has exceeded consumption of cotton, the next largest volume fiber, and also accounts for about 40% of consumption of synthetic fibers by U.S. mills.

In August, cotton prices fell substantially and have just recently recovered somewhat. Lower cotton prices coupled with relatively stable polyester prices suggest that fabrics made of blends of these two fibers will be shifted toward a higher cotton content.

Imports, however, have had the big-

gest effect on polyester demand. Apparel imports, combined with fashion changes, have especially hurt filament demand during the 1980s. Consumer demand has shifted toward spun fabrics (either knitted or woven), which have an appearance closer to natural fiber (especially wool) fabrics. Consumer demand for fabrics made of filament fibers has favored imported apparel because of its lower cost. These trends have continued in 1986 as output of polyester staple fiber has risen, and that of filament has declined.

Not surprisingly, polyester fiber producers and textile mills using polyester are shifting their production toward products that can compete with imported apparel. In addition to lowering labor costs, all parts of the apparel manufacturing chain are working toward bringing out new garments with greater fashion appeal and better durability. Success of these programs waxes and wanes as foreign producers copy and supply similar garments and as fashion changes. However, apparel still accounts for about 50% of U.S. polyester fiber consumption.

The home furnishings use of polyester fibers has grown little. Recently, much of the growth has been in increased polyester use in bed linens and in upholstery (which includes fabrics used in automobiles). Both fashion and performance properties of polyester fibers have been responsible for these gains. Many of the other uses, such as fiberfill and curtain/drapery, are past major growth spurts and depend on demographic growth and replacing other materials for any gains.

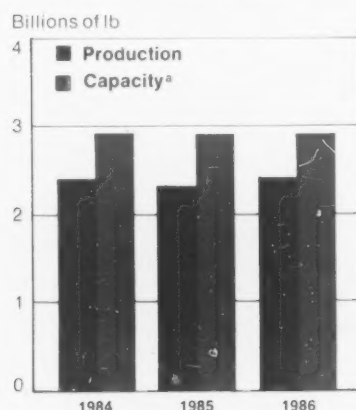
Industrial uses of polyester fibers amount to about 30% of total consumption and have been dominated by tire cord. The market for tire cord has declined because of changes in tire construction, size, and life, and tire imports. Belt and hose reinforcement growth has slowed. Currently, the fastest growing industrial use remains the nonwoven fabrics, which mainly use polyester staple.

Key Polymers

Nylon

- **Production up slightly**
- **Capacity on hold**
- **Prices improved**

PRODUCTION/CAPACITY



a First quarter

MAJOR PRODUCERS

Allied-Signal, BASF, Du Pont, Monsanto

HOW MADE

Nylon 66—adipic acid and hexamethylene diamine reacted to form hexamethylene diammonium adipate, which is polymerized by removal of water at elevated temperature, pressure; nylon 6—caprolactam and water reacted to form aminocaproic acid, which is polymerized by removal of water

MAJOR END USES

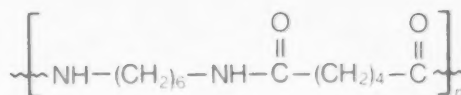
Home furnishings 65%, apparel 20%, industrial 15%

FOREIGN TRADE

Exports—to hold at about 140 million lb, imports—rising to about 150 million lb

PRICES

Carpet staple \$1.40 to \$1.70 per lb, low-denier textile fiber \$1.80 per lb



Nylon 66

Nylon fiber producers are expecting a better year than last. They also will have a better year than 1983 or 1984—the best production years since the peak in 1979. Consequently, they will use a higher fraction of the capacity that has held at close to 2.9 billion lb so far in this decade. Nylon fiber output has been increasing as a result of demand for carpet in housing and for specialty uses in apparel. Growth in carpet demand continues to outstrip that in other uses of nylon, including exports.

With estimates coming in on third-quarter production of nylon fibers, forecasts for 1986 total production are beginning to cluster around 2.45 billion lb, up more than 4% from 1985. It also would be more than the 2.41 billion lb produced in 1984. Fourth-quarter production will determine whether the total will reach a record 2.5 billion lb this year.

Capacity to make nylon fibers varies, and estimates of capacity are less precise than those of production. If, at the beginning of 1986, capacity held at 2.9 billion lb and the year's production totals 2.4 billion lb, then the average operating rate would be about 83%—higher than last year's rate of about 79%.

Prospects for the different nylons—6 and 66 (or 6/6)—are influenced by different segments of demand, which cause variations in operating rates. For example, several types of carpet nylon have remained in strong demand so far in 1986, requiring plants that produce the fiber for carpet to run at higher rates than those producing fiber for apparel and industrial uses. Nylon carpet fiber production is practically unaffected by imports. Except for specialty area rugs, little carpeting sold in the U.S. is imported. By contrast, various apparel uses of nylon fibers have been affected by imports of nylon apparel—enough to cause a demand decline in recent years. The differences in the impact of imported fabricated products on consumption

of nylon depends on the amount of labor required in the fabrication. Carpet, for example, now requires much less labor for its manufacture because of developments more than 30 years ago in tufting machinery and in the bulked continuous-filament textured yarns.

Because of these developments in nylon fibers and carpet making, nylon has dominated the carpet fiber market since the early 1970s. Efforts by producers of other fibers to move into this market generally have been rebuffed, as nylon fibers were improved in such properties as stain resistance, durability, and elimination of static shock. Polypropylene has increased its share of carpet fiber consumption, but it has been at the expense of polyester's use in carpet.

A newer development, that of the "carpet tile," has helped nylon. The squares of completed carpet appeal to do-it-yourselfers because of ease in installation.

Other factors also are spurring nylon carpet demand. From a commercial standpoint, carpeted areas are less expensive to maintain than vinyl or other tiled areas. Furthermore, capital costs are not that much different, allowing carpet to continue its hold on this market.

Apparel use of nylon has turned up again after a long slide. Much of the modest growth stems from increased demand for nylon fibers in outerwear garments, where competition from imported apparel still is strong. Fashion also influences the selection of fiber for many apparel uses, causing some variation in demand from year to year.

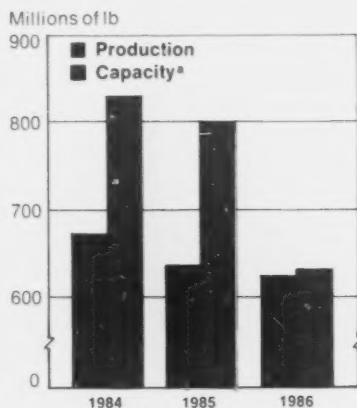
Industrial use of nylon includes tire cord, a market that has slipped away from nylon except for heavy-duty tires. Even these markets are being eroded by polyester and steel as well as rising imports of tires and lower sales of farm equipment. Other industrial markets, such as belting and hose, are not growing.

Key Polymers

Acrylics

- **Production slipping**
- **Capacity reduced**
- **Prices up slightly**

PRODUCTION/CAPACITY



MAJOR PRODUCERS

American Cyanamid, BASF,
Du Pont, Monsanto

HOW MADE

Polymerization of acrylonitrile with
small amounts of other acrylate
comonomers

MAJOR END USES

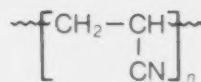
Apparel 65%, home furnishings
30%, industrial 5%

FOREIGN TRADE

Exports—dropping to below 100
million lb, imports—rising to about
65 million lb

PRICE

3-denier staple for apparel about
85 to 95 cents per lb



Polyacrylonitrile

Production of acrylic fibers turned around this year. Output of these fibers—smallest in production volume of the major noncellulosic, nonolefin synthetic fibers—increased this summer on the strength of rising demand. Earlier indications were for another year of decline in production.

Last year's extensive capacity shutdown also has been reversed, with some capacity restarted as early as midyear. Inventories have been drawn down, which could mean that relatively high production rates will continue for some time even if demand should fall. However, exports, which could slide to about half the 1985 volume, constitute one big negative factor facing acrylic fiber producers.

A production surge in the third quarter has boosted this year's output of acrylic fibers, including the modacrylic fibers. (Modacrylics contain less than 85% acrylonitrile as well as other comonomers, mainly chlorinated hydrocarbons such as vinyl chloride.) Output will nearly match, and possibly slightly exceed, the 631 million lb produced last year. Output in 1985 decreased 6% from the previous year's production of 671 million lb. That decline led to forecasts for a 5% decline in 1986 production to 600 million lb, based largely on a projected decline in exports.

During the first half of 1986, production was off less than 5%, about in line with forecasts. Then, demand for acrylic fibers in some fabrics, such as fleeces used in warmup suits, expanded and began to push production because inventories had been reduced during the first half of the year. Consequently, production has been stepped up to meet added demand and to build more inventory. Production in the second half of the year now is forecast to be up 5 to 10%, offsetting the decline in the first half and allowing 1986 output to about match that of 1985.

If output does hit 630 million lb, capacity will have to run at nearly 100% of the average nameplate total

for the year. After various shutdowns of capacity in 1985 and earlier, capacity at the beginning of 1986 was about 630 million lb. At mid-1986, Du Pont reported startup of 20 million lb of shutdown capacity, thereby adding about 10 million lb to the nameplate for the year. Other capacity startups, plus a small amount of debottlenecking and spinning-process improvements, could add slightly to the capacity total.

Actual U.S. consumption of acrylic fibers has increased even while production was declining. Domestic shipments of acrylic fibers in first-half 1986 rose more than 18% over the year-ago level. This gain reflects the demand growth for the fiber in fleece garments, a further shift toward acrylic fiber use in sweaters, spurred partly by fashion changes, and growth in other smaller end uses.

A gain of 41.8 million lb in first-half domestic shipments was more than offset by a decline in exports of 55.1 million lb, a slump of more than 50% from exports in first-half 1985. The decrease in exports so far this year—reduced by the gain in domestic shipments—accounts for about half of the production decline, with the remainder caused by inventory reduction and a small increase in imports of acrylic fibers.

Although domestic shipments of acrylic fibers for making fabrics (circular knits) that go into fleece garments and for making sweaters has improved, the consumption pattern for acrylic fibers is not changing appreciably. Apparel will continue to dominate. Textile companies have improved their competitive position, relative to imports, through modernization of their knitting plants and through advances made in fabrics to attract designers toward acrylics. The other major end-use categories, home furnishings—large'y blankets, draperies, and outdoor items such as awnings and furniture covers—and industrial, are growing moderately, but not enough to greatly influence demand for acrylic fibers.

Optimism Returns to Mexico's Petrochemical Industry

New government edicts give private sector more freedom to operate and recent government report details long-term plan for industry

Earl V. Anderson, C&EN New York

After an absence of several years, optimism has returned to the Mexican petrochemical industry. With the country still facing severe economic problems, an inflation rate that's flirting with the 100%-per-year level, and a huge foreign debt, it's a guarded optimism, to be sure.

Nevertheless, Mexican petrochemical producers, particularly in the private sector, feel more confident about their future than they have

in a long time. Recent developments have combined to generate this new burst of optimism. New government edicts give the private (secondary) petrochemical sector new freedom to operate. And a recently issued government report spells out more realistic long-term goals for Mexico's petrochemical industry and outlines a plan to achieve them.

In addition, Mexican chemical companies are encouraged by the fact that Mexico has finally joined the General Agreement on Tariffs & Trade (GATT). Carlos Pani, director general of ANIQ, Mexico's chemical industry trade association, says that if the industry wants to export—and it does—it must play by the rules of the world export market. "We can't be a major chemical exporter if we continue to play by our own rules," Pani says.

Contrary to many other Mexican industrialists, the country's petrochemical producers welcome the competition that GATT membership surely will bring. They are convinced the industry must become a more efficient producer. The new international competition that will result from belonging to GATT will act as an incentive to achieve new levels of efficiency, Pani says.

But GATT membership alone isn't responsible for the industry's newfound optimism. Last month, the federal government issued a resolution that redefined primary and secondary petrochemicals. By law, primary petrochemical output in Mexico is reserved for *Petróleos Mexicanos* (Pemex), the state oil company.

Generally, primary petrochemicals include the basic materials such as ethylene, propylene, and benzene and first derivative products such as ethylene oxide and polyethylene. The private, secondary petrochemical sector could produce only products that were further downstream.

Now, however, the new redefined lists allow the secondary petrochemical industry to make several products that previously were reserved solely for Pemex. Among the more important products is polypropylene.

Among the 36 petrochemicals now listed as secondary petrochemicals are several already produced by private companies, but by old, inefficient processes. The new resolution now allows these products to be made by more efficient processes than those currently used. These products include vinyl acetate, acetic acid, acetic anhydride, butyl alcohol, butyraldehyde, and 2-ethylhexanol.

This new resolution can be criti-

These products are tagged for investment priority in Mexico

Thousands of metric tons per year	Minimum desired capacity	Minimum desired capacity	Minimum desired capacity
INTERMEDIATES			
Terephthalic acid	70	Acetic anhydride	—
Acrylates	30	Benzoic acid	1.5
Maleic anhydride	6	Bisphenol-A	10
Sodium cyanate	8	Chloromethanes	45
Divinylbenzene	12	Ethyleneamines	1.5
Dimethyl terephthalate	40	Butyraldehyde	90
2-Ethylhexanol	40	Caprolactam	50
Phenol	50	RESINS	
Nitric acid	100	Styrene copolymers	1.5
Nitrotoluene	40	Polyethylene terephthalate	30
Toluenediamine	20	Acrylonitrile-butadiene-styrene	15
Aniline	30	Polyvinyl alcohol	3
Acetanilide	30	Polystyrene	40
Hydroquinone	3	Polycarbonates	8
Vinyl acetate	120 ^a	Polyvinyl butyral resins	3
Acetic acid	—	FIBERS	
		Polyester	20
		ELASTOMERS	
		Styrene butadiene	25
		Polybutadiene	25
		Butyl	30
		Thermoplastic elastomers	10
		Nitrile	3
		Chloroprene (neoprene)	10
		SPECIALTIES	
		Benzaldehyde	5
		Glyoxal	1.5
		Dichloroaniline	12 ^b
		Methionone	3

^a Capacity includes acetic acid and acetic anhydride. ^b Capacity includes coproducts such as diphenylamine and nitroaniline. Source: Secretaria de Comercio y Fomento Industrial

Mexico thinks its position as basic petrochemical exporter will deteriorate

Competitive level	Basic petrochemical export strength, 1982					Basic petrochemical export strength, 2000				
	Ammonia, methanol	Ethylene	Propylene	Butadiene	Aromatics	Ammonia, methanol	Ethylene	Propylene	Butadiene	Aromatics
Strong	Mid-East Canada	Mid-East Canada	West Europe U.S.	West Europe U.S.	U.S.	Mid-East Canada Oceania	Mid-East Canada			U.S. East Europe
Favorable	Mexico U.S.	Mexico U.S.	Mexico Mid-East	Mid-East	Canada West Europe Japan		Oceania	Canada Mexico U.S.	West Europe U.S.	West Europe
Vulnerable	West Europe	West Europe	Japan	Japan Mexico Canada	Mid-East Mexico	Mexico U.S.	Mexico U.S.	Mid-East West Europe Oceania	Mexico	Mexico ^a Canada
Weak	Japan	Japan				East Europe West Europe	East Europe West Europe	East Europe	Mid-East Oceania	Mid-East Oceania

a Competitive level falls between favorable and vulnerable. Source: Pemex (Petróleos Mexicanos)

cized as inconsistent. Polypropylene, for instance, can now be made by private companies but polyethylene still cannot. However, Lars Christianson, director of Christianson S.A., calls it "a tremendous step forward."

How many private companies will actually take advantage of this new petrochemical ruling remains to be seen. The Mexican rumor mill has it, however, that some Mexican companies and possible U.S. partners are seriously considering polypro-

pylene, propylene oxide, and butyraldehyde.

Private petrochemical producers in Mexico also have won freer access to imported raw materials. Until recently, they had to get all of their petrochemical raw materials

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from Pemex. If Pemex couldn't produce enough to meet demand—as was often the case—then Pemex would import the basic petrochemicals and resell them to its customers.

Now secondary petrochemical producers in Mexico can import their primary petrochemical raw materials directly, without having to use Pemex as an intermediary. This, says one Mexican chemical industry observer, is another step toward allowing the secondary petrochemical industry to operate in an open economy.

As a morale builder, a recently released government report is just what the doctor ordered for Mexico's private petrochemical producers. This report, a joint effort of the Secretaria de Comercio y Fomento Industrial; Secretaria de Energia, Minas, e Industria Paraestatal; Pemex; and ANIQ, was three years in the making.

ANIQ's Carlos Pani says that it was worth the wait. The report def-

initely establishes the petrochemical industry as a "priority" industry. And, although the report has no power of law behind it, it does have a lot of power of persuasion.

The report, An Integrated Program for Petrochemical Industry Development, covers a lot of subjects, from technology and environmental policies to regional development and fiscal policies. Its major thrust, however, is to make Mexico's petrochemical industry a major exporter with a substantial balance of trade surplus.

In the report, Mexico finally recognizes what international chemical experts have long known—Mexico has a weak and declining position as an exporter of basic petrochemicals. As a result, the report stresses that the best way for Mexico to export primary petrochemicals is to convert them in Mexico to secondary petrochemicals and end products, then export these materials to world markets.

Using this strategy, the report says that basic petrochemical demand to make exportable products likely will reach 30% of domestic demand for the basic petrochemicals. If so, total basic petrochemical demand in Mexico will reach 27.2 million metric tons in the year 2000, three and a half times what it was in 1983.

This strategy has a price tag, however. To completely satisfy domestic demand and have enough basic petrochemicals left to convert to upgraded products for export, Mexico will have to invest an average \$800 million per year between 1986 and 2000. This investment is expected to enable Mexico to eliminate an average \$250 million annually in basic petrochemical imports and produce an excess of \$600 million per year of basic petrochemicals. But this \$600 million excess, says the report, can be transformed into \$6 billion worth of exportable products. □



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News of the Week

■ Bhopal case legal battles between the Indian government and Union Carbide heat up again on several fronts. **Page 4**

■ EPA wants to collect fees from manufacturers for registering pesticides. **Page 5**

■ Hans Stauffer, a former president of Stauffer Chemical, is dead at 85. **Page 6**

■ Low-weight fuel cell produces higher power density than previous cells. **Page 6**

■ Cabot Corp. announces selection of new president and adoption of shareholder rights plan. **Page 6**

Cover: Photo courtesy of National Aeronautics & Space Administration

Letters 2
Editor's Page 3

Concentrates
Business 7
Government 10
Science/Technology 12

The Departments
ACS News 66
Newscripts 80



The Changing Atmosphere

Global warming and depletion of stratospheric ozone confront mankind with many unknowns and put technology and social and economic policy making to the test. **Page 14**

Science of the problems

Models calculate that changes in composition of the atmosphere, caused by increasing levels of chlorofluorocarbons, carbon dioxide, and other trace gases, will lead to ozone depletion and climate warming. **Page 16**

Social, economic implications

Current estimates of the effects of ozone depletion and global warming depend on incomplete science; more socioeconomic studies need to be undertaken, but initial steps for energy conservation can be taken now. **Page 36**

Response to ozone depletion

Chlorofluorocarbon industry searches for substitute materials; U.S. industry agrees to limit global CFC production capacity but, to be effective, controls must be imposed internationally. **Page 47**

Response to global warming

Congress is stepping up its pace in dealing with the legislative aspects of climate warming; coordination needed to pull together research scattered among federal agencies. **Page 56**

each attempted such a calculation. By different routes, they arrived at the same number. The global costs for doubling carbon dioxide levels amount to about 3% of gross world product. Three per cent is also about the rate of economic growth worldwide. So the global costs for doubling carbon dioxide levels would "bring economic growth to a halt," Laurmann says. (Also, the simple axiom holds: The longer controls are put off, the more expensive they become.)

Getting more specific is also difficult. One of the best-studied areas is the secondary effect of global warming: sea-level rise. EPA's project manager for sea-level rise Titus says, "Nobody has estimated what it would cost to defend against a 2-meter rise in sea level. There are no nationwide or worldwide estimates." The task is complicated, Titus explains. "Is the total cost of building dikes to defend against this rise merely the cost of the loss of wetlands, or is it the cost of the dikes plus restoration of the wetlands?" The answer is important because a 1- to 2-meter rise in sea level by 2100 could destroy up to 80% of U.S. coastal wetlands.

There are place-specific estimates for a 1-meter rise or less, however. A 28-cm to 64-cm rise would cost Charleston, S.C., about \$280 million to \$1.07 billion in current dollars, or about 5 to 19% of economic activity, through 2025. If the sea-level rise was anticipated, the costs would drop to \$160 million to \$420 million. Most of this expense would come from increased storm damage. Similarly, the impact on the Galveston, Tex., area for the same sea-level rise and for the same time frame would be \$115 million to \$360 million, or 1.1 to 3.6% of economic activity, if unanticipated, and \$80 million to \$140 million if anticipated.

Studies by Woods Hole Oceanographic Institution indicate that a 1-meter rise would have devastating effects on Bangladesh. Nearly 12% of the land area, 9% of the population, and 11% of agricultural production would be affected.

Anthony E. Scoville, freelance writer and former technical consultant to the House Science & Technology Committee, suggests a way

out of the greenhouse dilemma for a country like the U.S. What is needed is "to develop an economy that can better anticipate future trends, whether they are economic or environmental trends." In his yet to be released book "Climate & Capital" (Walker & Co.), he explores mechanisms that might be used to "put more foresight into our economy."

"The first thing you have to do is mobilize very large-scale savings through retirement and pension plans. That's where all the new capital is being formed in this country. Second, you have to do something about reforming the banking system so that the discount rates on short-term fund flows don't start conflicting with the longer-term investment needs, which are made on a cycle of up to 50 years." If the proper steps are taken, "This could be advantageous not only to the environmentalists but also to the people concerned about meeting technological competition," he adds.

Planetary bargain

From his studies, University of Illinois, Chicago, economist Richard F. Kosobud has concluded that it will be very difficult to get international agreement on cooperative carbon dioxide policies. Some countries may benefit from global warming, others may not.

How do developed countries respond to the concerns of the developing nations? NCAR's Schneider says, "What is needed is the concept of a global survival compromise, or a planetary bargain to quote Harlan Cleveland." Under such a regime, "the wealthy countries agree that their problem is conspicuous consumption, and the poor countries agree that their problem is population and poverty." The wealthy nations put up the resources to help the poor ones develop, beginning at the lowest strata of society. The poor nations agree to reduce population growth.

Asked how this can be implemented, Schneider answers: "Good luck!" And, he adds, "I believe the greenhouse gas problem represents the failure of the world to grapple with its single most important issue, which is global development." □



Response to ozone depletion

Easier to grapple with both politically and economically is the threatened depletion of the ozone layer 12 to 50 km above Earth's surface. In this part of the atmosphere, called the stratosphere, ozone acts to shield all living and nonliving things on Earth from most of the sun's harmful ultraviolet radiation.

Governmental efforts to stem this possible net ozone depletion have focused on man-made CFC emissions because the sources are known and controllable. For nitrous oxide, another ozone depleter, the sources are not well defined. Fertilizers and combusted fossil fuels are suspect sources, but these would be difficult to control.

Still, control of CFC emissions presents policy makers with troubling dilemmas. The effects of significant ozone depletion are likely to be large, and become apparent anywhere from decades to centuries into the future. Equally long term will be the time these effects play out. As NASA scientist Robert Watson explains, any regulatory measures now have to be taken on "a potential environmental problem that is based largely on theory."

To confound policy makers further, CFCs are useful—some would say essential—versatile, nontoxic, and nonflammable. They find wide application in refrigeration, in air conditioning, in plastic foams for insulation and packaging, as cleaning agents, and as sterilants for med-

The Changing Atmosphere

ical supplies and devices. The Alliance for Responsible CFC Policy, an association of more than 500 CFC producers and users, has tallied U.S. CFC-related goods and services. The alliance claims they are worth more than \$28 billion a year, and represent 715,000 jobs.

Because of the potential harm increased UV radiation poses to land and sea life, and to such man-made materials as plastics, some governments already have imposed bans on what they consider nonessential CFC uses. In the U.S., EPA and the Food & Drug Administration took such action in 1978, banning the use of CFCs as aerosol propellants in nearly all consumer products.

Two years later, EPA proposed to consider additional regulations on all other uses of CFCs. The agency has yet to act on this proposal, even to the extent of stating that no further regulations are needed. But under a consent agreement with the Natural Resources Defense Council (NRDC), EPA, by next May, will have to declare whether it intends to issue further regulations.

Until very recently, producers and users of CFCs argued that further regulations were uncalled for until science proves the ozone-depletion theory valid. They reasoned that the global decline in CFC production, which fell and stayed below the 1974 peak level until 1983, bought time to develop scientific understanding without harming human health or the environment. They still believe that current emissions pose no immediate hazard to human health or the environment.

CFC industry shifts policy

Still, this fall producers and users of CFCs changed their position. In September, the alliance said it would support "a reasonable global limit on the future rate of growth of fully halogenated CFC production capacity." Fully halogenated CFCs, such as the most widely used CFC-11 and -12, are potentially the most robust depleters of stratospheric ozone. That same month, the nation's leading CFC producer, Du Pont, released its own statement that spokesman James Adshead concedes "may have gone a little bit beyond the alliance position."

Du Pont called for a limit on worldwide emissions of CFCs. "What that limit should be," Adshead says, "should be negotiated under the auspices of the United Nations Environment Program (UNEP)."

With 40 to 50% of the U.S. market and 20 to 25% of the world market—about \$30 billion in total annual sales—Du Pont has muscle. According to EPA sources, the company flexed its muscle in 1978 and dissuaded the agency from taking more stringent measures than the aerosol ban it then put in place. This year's policy shift has been praised by some within EPA as an important first step, one that primes the pump for regulatory action. And the environmental group NRDC has proclaimed Du Pont's policy change "the biggest breakthrough" since EPA's 1978 aerosol ban. Why the industry shift?

Though the unexpected and still unexplained Antarctic ozone hole probably brought industry scientists and managers up short—as it did every researcher studying stratospheric ozone—a government scientist does not believe it to be a major factor in industry's reassessment. Several industry spokesmen confirm this. However, one, Allied-Signal's S. Robert Orfeo, chairman of the Fluorocarbon Program Panel of the Chemical Manufacturers Association, thinks "EPA might use the Antarctic hole as additional leverage to regulate." Not true, says John S. Hoffman, chairman of EPA's stratospheric protection task force. "We are not planning to base our decision making on Antarctica."

What did force industry to reevaluate its position, NASA's Watson believes, was the evolving science. Most scientists now agree that "large unbridled growth in the CFC industry would put enough chlorine into the atmosphere to deplete stratospheric ozone [significantly]," he says. Indeed, alliance spokesman Kevin Fay says, "large, unrestrained growth in CFC usage may lead to large future ozone depletion."

For many years, CFC production, and therefore demand, was essentially level. That changed in 1983 when CFC nonaerosol use began to climb. It continues to increase.

According to EPA, through the year 2000, the global short-term demand picture for the three most widely produced and used CFCs is for flat demand for aerosol applications of CFC-11 and -12; growth in the demand for CFC-11 and -12 in nonaerosol uses, particularly in the foam sector, at a rate paralleling economic growth of about 3% per year; and growth in the demand for CFC-113 ($C_2Cl_3F_3$) in solvent/cleaning applications, at a rate greater than economic growth, or about 5% per year. The long-term, or post-2000, projections are for continued worldwide growth. However, growth will level off in the developed countries and expand in the developing countries. The long-term demand growth for CFC-11 and -12, assuming mid-range future economic and population growth and technological change, is about 2.5% per year.

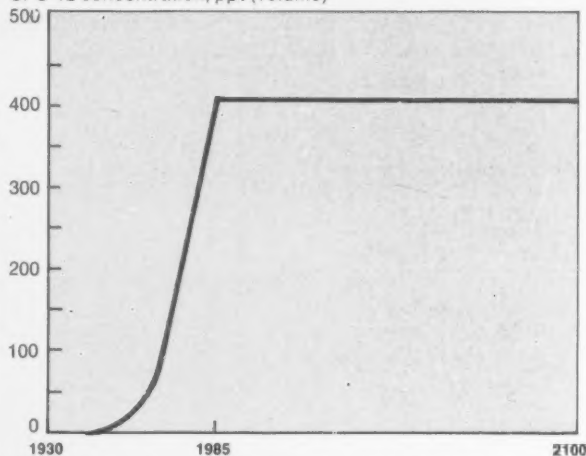
Watson also believes that another factor prodding industry's re-evaluation is the 1985 international ozone convention. That convention, signed by more than 20 nations and ratified by the U.S. and the U.S.S.R., calls for negotiating a protocol to protect stratospheric ozone. UNEP negotiations on such a protocol are to begin in Geneva next month. The outcome might be some sort of CFC production cap, or emissions limit.

Indeed, in a statement to customers explaining why it deems it prudent to limit worldwide CFC production, Du Pont confirms Watson's assessments. In the statement Du Pont cites these facts:

- The recent upward turn in global CFC production and use, which now has reached levels that prevailed before the 1978 aerosol ban.
- The fact that all models now predict that a high sustained growth in CFCs, leading to emission levels 3 to 5% above current levels, would result in significant future ozone depletion.
- The contribution CFCs make to the climate warming produced by carbon dioxide and other trace gases, which some in industry say is about 15 to 20%, although several scenarios EPA uses place the contribution at about 30%.
- "The existing inability of the science to specify a safe long-term growth rate."

To hold levels of CFC-12 constant...

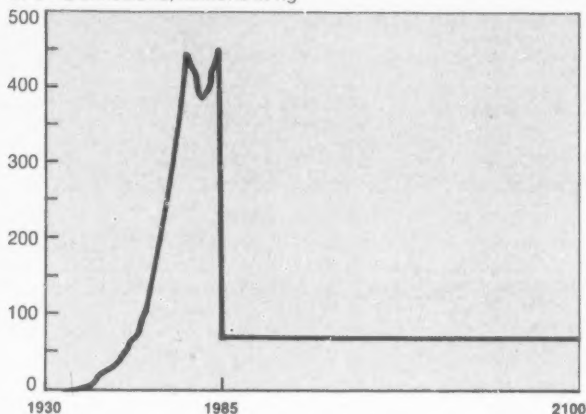
CFC-12 concentration, ppt (volume)



Emissions of chlorofluorocarbon-12, which has a lifetime of about 110 years, would have to be cut about 85% to hold its atmospheric concentration constant at today's level of about 400 ppt (volume). Levels of other long-lived CFCs, such as CFC-11 with a lifetime of about 75 years, behave similarly

... emissions would have to be cut deeply

CFC-12 emissions, millions of kg



With shades of the 1978 unilateral, use-specific aerosol ban darkening present U.S. regulatory horizons, industry has been quick to stress the undesirability of a repeat episode. Indeed, alliance chairman Richard Barnett, who is vice president and general manager of York International Corp., a CFC user company, says, "If the U.S. takes unilateral action, it takes the pressure off the rest of the world to act" to agree to an international accord. The association also insists that "regulation of specific uses of CFCs is ineffective and discriminatory."

According to the association's Fay, his group wants EPA to delay further regulations until there is an international protocol. Du Pont has gone one step further. It has asked EPA to consider using a regulatory negotiation process to reach a consensus position on any unilateral action EPA may take next year, and on the strategy the State Department will adopt this winter during protocol negotiations. As envisioned by Du Pont, the consensus position would be hammered out among EPA, the CFC industry, and environmental and public-interest groups.

"We would like to see an international protocol next year. We'd like to see that process go in parallel with the domestic process," says Richard Benedick, deputy assistant

secretary of State for environment, health, and natural resources. Benedick, who will head the U.S. delegation to the Geneva meeting of some 40 nations, adds, "We don't want again to have a situation where the U.S. regulates domestically while the rest of the world sits back. I don't think that will happen."

The nation's second and third largest CFC producers, Allied-Signal and Pennwalt, also support the alliance policy. (Racal and Kaiser Chemical, the remaining two U.S. producers, had no comment.) According to Charles Coe, director of public affairs for Allied-Signal's engineered materials sector, his company especially agrees with the alliance's stress on "the international nature of this issue. It has to be addressed on a global basis."

"Until an international agreement is in place," Fay says, U.S. producers and users "plan to develop programs to decrease emissions." Both the alliance and Du Pont have already called for voluntary action by CFC producers and CFC end-user industries to reduce emissions through improved conservation and recovery practices.

Search for safe alternatives

Alliance chairman Bartlett says another way to manage the potential problem is for producers to devel-

op new chemical formulations, and to shift production to these new, ozone-benign substitutes. According to Du Pont's environmental manager for the Freon products division, Joseph M. Steed, "The development of alternatives is going to happen at a rate that corresponds to the amount of pressure that is applied. Right now there is no economic or regulatory incentive to look for other routes."

Unilateral or global pressures could come from a production or emissions cap, a consumption or use cap, a tax on production, or marketable permits. "Any of these approaches has some kind of implementation difficulty," Steed cautions. But they all have one virtue. "They would raise the price of current products and/or tighten the market so that demand would increase for substitutes. In a sense, the market forces the development of substitutes or forces choices among uses. You might see certain parts of the market being very price sensitive—most likely the less essential uses—and these would drop away," Steed says.

Alan S. Miller, visiting assistant professor at the Washington (D.C.) College of Law, American University, says, "The ideal policy would be an international production limit set at current production, plus an

Chlorofluorocarbons find many and varied applications

Application, type of CFC used	Key characteristics of CFC used	Interaction with society	Economic scope (annual)	
			Value of products/services (\$ billions)	Direct CFC-related industry employment (thousands)
Refrigeration CFC-11 CFC-12 CFC-22 CFC-500 CFC-502	Thermodynamic properties Safety Cost	85 million household refrigerators 160,000 food stores 28 million household freezers 39,000 supermarkets 178,000 refrigerated trucks 250,000 restaurants 27,000 rail cars	\$ 6	52
Air conditioning CFC-11 CFC-12 CFC-22 CFC-113 CFC-114	Thermodynamic properties Safety Cost	40 million homes; essentially all office, commercial, and public buildings	10.9	125
Mobile air conditioning CFC-12	Thermodynamic properties Safety Cost	60 million to 70 million automobiles and trucks (total in use)	2	25
Plastic foam CFC-11 CFC-12 CFC-114	Thermodynamic properties Safety Cost	Insulating foams for homes, refrigerators; food service trays and packaging; cushioning foams	2	40
Solvents CFC-11 CFC-113	Ability to displace all contaminants Chemically inert Safety	Microelectronic circuitry, high-performance air and spacecraft, and computers	Products valued at billions ^b	
Food freezants CFC-12	Thermodynamic properties Toxicologically safe Cost	Frozen shrimp, fish, fruit, vegetables	0.4	Less than 1000
Sterilants CFC-12	Nonflammability (safety)	Medical items, catheters, syringes, respiratory units, medical supplies, pharmaceuticals	0.1 (sterilizing equipment)	Less than 1000
			TOTAL \$26.9^c	715^c

^a Today CFC-22 and a blend of CFC-22 and CFC-142B can substitute for CFC-11 and CFC-12 in air conditioning and refrigeration with equipment modification. ^b Industry complexity precludes more detailed analysis for this report. ^c Does not include solvents, but does include all existing CFC refrigerators and air conditioners whose value equals \$5.5 billion and employment amounts to 472,000. **Source:** Alliance for Responsible CFC Policy

emissions tax." Such a tax would be a substitute-forcing mechanism. It "would discourage long-term growth in emissions [but] it would be difficult to administer," Miller notes. Almost as effective, he says, would be a tax on production, with credits for documented recovery or destruction of CFCs.

Because CFCs accumulate in the atmosphere, the higher their short-term growth rates are, the greater will be the potential societal costs accompanying future regulation, Miller says. He also warns that producers could be hit with devastating costs if they are forced to reduce emissions rapidly.

"Industry has not greeted my pro-

posal with overwhelming enthusiasm," Miller admits. "But [producers] can see one possible benefit from a tax—it would provide some certainty about future price," he says.

Industry, to put it mildly, was also not very enthusiastic about the 1978 aerosol ban. The ban did, however, prove to be an incentive—but a flawed one. "It did not provide any incentives for innovation in other areas, but it did get a lot of reduction," EPA's Hoffman says. Steed characterizes this use-specific ban as "disruptive" because it was imposed "too abruptly." Pennwalt's Julius E. Dohany, who is director of research and development for the

fluorochemicals division, also cautions that further EPA actions or international controls should be phased in. "A transitional period will be needed," he insists.

Europeans to this day are against specific use bans. Says European Fluorocarbon Technical Committee's (EFCTC) John F. D. Mills, "Banning specific uses is very expensive; the social costs are high." He adds: "The longer you allow for adaptation, however, the easier the job, and the better the costs can be absorbed."

His argument was supported by the Japanese delegates to the UNEP/EPA Leesburg, Va., meeting in September on the socioeconomic implications of CFC control. Repre-

Direct potential alternatives ^a	Consequences of using alternatives
Ammonia Sulfur dioxide Methyl chloride	More toxic, combustible, corrosive, explosive, less energy efficient
Ammonia Sulfur dioxide Methyl chloride	More toxic, combustible, corrosive, explosive, less energy efficient
Ammonia Sulfur dioxide Methyl chloride	More toxic, combustible, corrosive, explosive, less energy efficient
None for high-efficiency insulation Pentane (some foams) Methylene chloride (some foams)	Less effective insulation, combustible, processing difficulties, toxicity
Perchloroethylene Trichloroethylene Trichloroethane	More toxic, use more energy
Cryogenic systems	Higher costs, use more energy, inferior quality food products, more costly to ship, use less consistent sterilization
Carbon dioxide	

sentatives of the Japan Flon Gas Association, and the Japan Aerosol Association reported that Japan's rapid cutback in CFCs used in aerosol products created a loss of aerosol markets, with an attendant increase in initial costs of converting equipment capable of handling other propellants. Consequently, the Japanese also called for a transition period.

Some in the U.S. environmental community agree that a transition period is needed to phase out the current CFC "bad actors," and to phase in more benign chemicals. Also at the September UNEP-EPA meeting, NRDC called for U.S. regulations and for an international

agreement on a five-year phaseout of most of the production of the commercially available chlorine-containing CFCs and the bromine-containing Halons. Halons are used to extinguish fires in which the use of water would be harmful.

NRDC's plan calls for a 30% cut in these chemicals in 18 months. NRDC senior attorney David D. Doniger says this can easily be achieved globally by banning the aerosol use of CFCs in nations not yet restricting this use, and by prohibiting the use of blown foams for food containers in the U.S. (According to Allied-Signal's Orfeo, "blown foams from which egg crates and fast-food containers are made are very vulnerable to control.") The next step would be an 80% cut in production by the end of five years, and a complete phaseout in 10 years.

However, Doniger warns that even this time frame may be too long, and CFC cuts will have to be made now if the Antarctic hole can be linked to chlorine, or if the NASA satellite data showing ozone depletion at all latitudes can be confirmed. "Then we will be facing an emergency that will make Chernobyl [reactor accident] look like a trash fire at the county dump," he says.

Barring such an emergency, Doniger admits that selling the EEC countries on NRDC's phaseout plan will be very difficult. But, even if the EEC countries resist the plan, it should be imposed unilaterally on U.S. industry by EPA, he insists. However, he says EPA regulations also should "prohibit the import of CFC-derived products from those countries that have not agreed to the phaseout." For example, CFC-cleaned computer chips from Japan could be barred if Japan is not a party to a phaseout program. He thinks such a trade barrier might even be welcomed by U.S. producers.

Available and possible substitutes

CFC-22 (CHClF_2), which is environmentally safer than CFC-12, can be substituted for CFC-12 in mobile air conditioning with proper engineering changes. Thus, it can act as "a bridging compound" during the transition to chemicals such as CFC-123 ($\text{C}_2\text{HCl}_2\text{F}_3$) and -134a ($\text{C}_2\text{H}_2\text{F}_4$),

which are even safer because they decompose in the troposphere, Doniger explains. Syntheses of these latter hydrogen-containing CFCs are known, but the compounds themselves are not available in commercial quantities. And they have yet to pass toxicity tests. Assuming they do so and become available in large volume, they can substitute for CFC-11 and -12 in refrigeration and air conditioning, Doniger says.

Doniger says U.S. CFC-user industries are pressuring U.S. producers to find safe substitutes for the major long-lived chlorine- and bromine-containing compounds now used. [These are basically CFC-11, -12, -22, -113, and Halon-1211 (CBrClF_2) and -1301 (CBrF_3).] Users are uncomfortable with the uncertain regulatory climate that could force existing CFCs from the market. They want to be assured of a stable supply—even at a higher price.

U.S. producers are facing other pressures as well. According to Doniger, "Rumors are floating that foreign producers may have a lead on U.S. producers in the area of substitutes." He has been told that the U.S. electronics industry believes the Japanese are hard at work on a substitute for CFC-113—the fastest growing compound in the CFC family. Its growth is pegged to the growth of the electronics industry where it is used widely as a cleaning solvent.

Whatever prods U.S. producers—be it phasedown regulations or foreign competition—"The CFC situation can be resolved by moving from one chemical to another [safer substitutions], and by wiser use of chemicals," Doniger says. By that he means better recycling and conservation. The phaseout program, he explains, "allows for a smooth transition for the industry and for consumers."

Interestingly, Hoffman says, "Environmentalists, on this issue, are calling for something innovative. They are not pushing us to do source controls." Yet he admits that EPA is "always going to be looking at the possibilities of doing source regulations"—that is, a specific use ban. But, he insists, the agency is "looking for something that is more innovative and will work better than"

The Changing Atmosphere

the aerosol ban did. "The thing we want to do is make sure that [industry] has the opportunity to use its talent, ideas, and knowledge to come up with better methods. We have to make sure that we provide them with the right regulatory environment because of the financial incentives it provides, the certainty it provides," he explains.

New products in five years

The current lack of regulatory or economic incentives has not dampened internal deliberations at Du Pont. Howard Simmons, vice president of Du Pont's central research and development department, says his company is "considering a limit on production capacity [if that's mandated by EPA], and is researching alternatives." There have been some discussions on setting a timetable for the introduction of replacement chemicals, Simmons says.

Du Pont spokesman Adshead confirms this. "We believe that if there were regulations that limited the growth of the existing CFCs, and if there developed from that a strong market demand, then in probably five years or a little more, some of [the substitutes] we are working on could be made commercially available." Allied-Signal's Orfeo says that Du Pont probably "has the products/substitutes on the shelf ready to go but for the toxicity testing, which would take five to 10 years."

According to Du Pont's Steed, the company began looking for substitutes in the mid-1970s under a research program that has cost about \$15 million. The research focused on fluorocarbons "that would avoid chlorine and would include hydrogen in the molecule," he explains. Lack of chlorine would eliminate the compound's stratospheric ozone-destroying potential, and the presence of hydrogen would prompt the molecule to break down in the troposphere.

Several compounds were eliminated in toxicity tests. Some could not be synthesized, or could not be produced without significant by-products. That left about a half-dozen chemicals, including CFC-22, -142b ($C_2H_3ClF_2$), and -152a ($C_2H_4F_2$).

CFC-22 is more costly to produce than the more widely used CFC-11



Watson: science prodded re-evaluation

and -12. It also would require expensive retrofitting by automobile and refrigerator manufacturers because it operates at higher temperatures and pressures. Existing equipment using CFC-11 and -12 would have to be redesigned to accommodate CFC-22's different physical properties.

CFC-142b and -152a are now produced in small quantities, as raw material for polymer production. They are expensive to make. And in addition, they are flammable, Steed says, and are not suitable substitutes in refrigeration, air conditioning, or solvent/cleaning applications.

The remaining unnamed chemicals show promise, Steed says. They



Orfeo: \$10 million for alternatives

are undergoing toxicity tests and process development. "If we were able to produce them, we know they would be several times as expensive to produce as current products, and that's assuming we can overcome the remaining problems," Steed adds. "At best [after all the expensive development and testing] we'll come up with something that is similar to what's already on the market at a much lower price."

According to Orfeo, Allied-Signal has spent more than \$10 million searching for alternatives. And still, spokesman Coe says, Allied-Signal "has not been able to find substitute products that have the same unique characteristics the CFCs as a group have." The company continues to look for alternatives. Coe says any decision on substitutes will have to factor in cost and retrofitting problems in the user sectors.

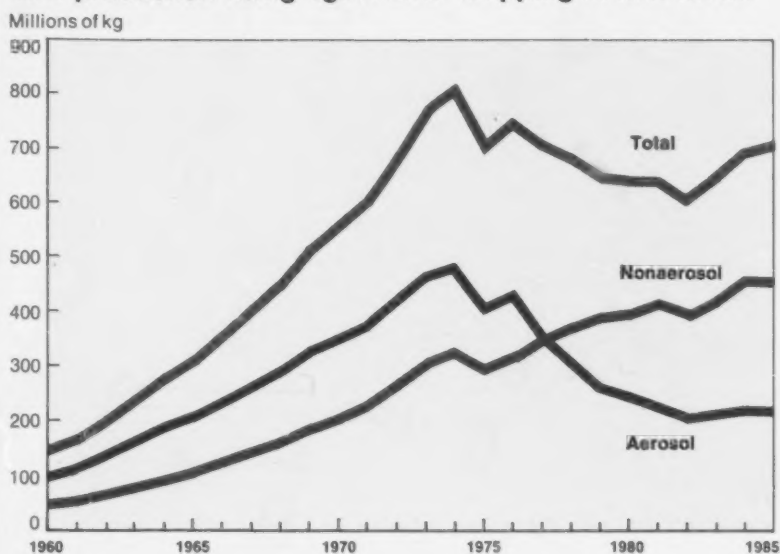
Dohany of Pennwalt says a blend of CFC-142b and -22 can substitute for CFC-11 and -12 in air conditioning. The blend's use, however, requires engineering modifications in end-use equipment. The same blend can substitute for CFCs used as aerosol propellants. Both compounds have passed critical toxicity tests. As mentioned, another promising chemical, CFC-134a, has yet to pass toxicity tests.

Search for control strategies

So while industry searches for substitutes, EPA searches for an equitable, and innovation-stimulating control strategy that will appeal to domestic producers. It also wants this strategy to entice other nations to agree to a global ozone protection program. In addition to NRDC's phaseout plan, three other options are being considered seriously. These are a production-capacity cap, a production cap, and the so-called Canadian proposal, which sets a global emissions ceiling that is implemented through national consumption (use) limits.

A production-capacity cap prevents additional plants from coming on-line and, according to EPA, implies a production limit. EEC has agreed to such a cap. The drawback is that European industry is probably at only about 70% of its full capacity, which means it could pro-

CFC production rising again after dropping in mid-1970s



Total reported production of chlorofluorocarbon-11 and -12 peaked in 1974 at 813 metric tons and declined fairly steady until 1983, when it began rising. Aerosol applications declined in the mid-1970s and are only now beginning to grow slightly, but nonaerosol uses have continued to increase. The production total for 1985 of 703 metric tons is the combined output of 21 companies in North and South America, Western Europe, Japan, Australia, Africa, and India. No information on CFC production from China, the Soviet Union, and Eastern bloc countries has been available since 1983. However, the U.S.S.R. recently reported its annual production capacity of CFC-11 and -12 is 60,000 metric tons, and China revealed its production capacity for those CFCs and several others is 18,000 metric tons. **Note:** The aerosol/nonaerosol divisions prior to 1976 are estimates.

Source: Chemical Manufacturers Association

duce at least 40% more CFCs per year. It also means that emissions could continue to increase into the next century before the cap became effective. In contrast, a production cap sets an absolute production limit. That limit could be set at the current production level; the 1974 production level, which was the highest ever; or 1.5 times the current level (which is about the EEC production capacity cap).

Europeans concede that controlling CFC uses (like an aerosol ban) would encompass production, imports, and exports. But as Mills points out, by controlling production, "you are controlling everything—not just CFCs in bulk, but CFCs in aerosol cans, in foams, and in refrigeration units." Because there are fewer CFC producers than users, Mills says control of production makes sense administratively.

European environmentalists are

not necessarily pleased with Mills' arguments. They say the EEC production-capacity cap doesn't curtail current use or emissions. In fact, total EEC CFC capacity has gone from 480,000 to 537,000 metric tons. Aerosol use has leveled off, but CFC use in foams for insulation and for industrial solvent cleaning has climbed significantly. However, EEC is putting much faith in its newly minted codes of practice, which it hopes will cut CFC emissions. Environmentalists concede that, in theory, the production-capacity cap would restrict growth in the future. But, they argue that a problem with setting production-capacity caps is that the price for CFCs could rise to a point where producers are making quasi-monopoly profits.

Christopher F. P. Bevington, an economist with the London-based Metra Consulting Group, who has done the economic and social cost/

benefit analysis of CFC control for EEC, tends to discount this concern. Though the price may be higher, he says, there is "more incentive to develop substitutes. Moreover, by complying with the production cap, manufacturers are forgoing the alternative of selling a lot more at lower prices. The profit margin might seem to be excessive, but probably not profits per se."

"From a purely scientific perspective, the logical [option] is a cap on the amount of chlorine being put into the atmosphere—a cap on emissions," NASA's Watson says. Although he says he has no special insight into EPA or UNEP deliberations, Watson believes "a number somewhere around one to one and a half times current production rates will be given the most serious consideration. There won't be major cutbacks, nor significant growth." (Production equals emissions to a first crude approximation.) Watson would be surprised "if there was a draconian cutback on the use of CFCs."

Pennwalt's Dohany also sees no outright ban, especially for CFC-11 and -12, "which are going to be needed for a long time to come." He believes the "likely outcome" of EPA deliberations will be threefold: stringent control on CFC releases, a phasing in of substitutes for CFC-11 and -12, and a ban of these two compounds by a certain date. This can all take place under some kind of internationally imposed production or consumption ceiling.

Canadian consumption proposal

The Canadian proposal is basically a global consumption limit. Consumption is defined as production plus imports minus exports minus recovery and conservation (if and when such programs are ever put in place). As proposed, 25% of the consumption limit would be allocated among nations based on their share of world population, and 75% of the limit would be apportioned among nations based on their share of the world gross product. Such a weighting would give developing countries a share of the global ceiling. This would allow them to produce CFCs if they choose to do so in the future, mainly for refrigeration purposes. The global limit could

The Changing Atmosphere

be set, Environment Canada suggests, at the maximum production level ever for CFC-11 and -12, which was 812,000 tons in 1974.

According to Hoffman, attendees at the September meeting expressed a lot of interest in the Canadian proposal. The proposal bridges the gap between the earlier U.S. and other countries' call for a worldwide ban on nonessential aerosol uses of CFCs, and the European call for a production-capacity cap. EPA is seriously studying the consequences of this proposal.

European delegates to the Leeburg meeting in September found the Canadian proposal "a constructive idea, worth thinking about," Bevington says. "But it was sprung at the last minute," leaving the Europeans with many unanswered questions. How would it be implemented? How enforced? Would CFCs per se be considered, or would CFCs imported in refrigerators be included, for example?

The key attraction of the Canadian plan is that each nation could decide which uses most need CFCs. France, for example, might decide that using CFCs as aerosol propellants in fragrances and mousses is important because CFCs make better products than alternative propellants do. On the other hand, Scandinavian countries might be more inclined to use CFCs in foam insulation as part of energy conservation efforts. And, of course, countries such as the U.S. might find CFC use in automobile air conditioning a socially significant application.

As equitable as the Canadian proposal appears, Bevington predicts that for the time being EEC delegates to the negotiations in Geneva will work with the present European system of a production-capacity cap. A spokesman for one European CFC producer concedes, "The production capacity in Europe is much less utilized than in the U.S. and Japan." He adds, "There may have to be a deal. EEC might have to reduce its production limits to try to even out the world situation."

From a bargaining standpoint, Miller says the U.S. should probably come to the negotiating sessions



Hoffman: something more innovative

with a proposal closer to the Canadian consumption scheme than to the European production-capacity cap. If it doesn't, he says, "the U.S. will end up with the European approach." The Canadian proposal, however, "addresses the second-order question of how to [set a limit], not the first-order question of what that ultimate limit" should be, Miller says.

If Bevington's prediction is accurate, getting the 12-nation EEC on board the Canadian proposal will not be easy. Britain, especially, is thought by knowledgeable U.S. sources to be very skeptical of the need for controlling CFCs. This perception may be incorrect, however.

According to Lucas Reijnders,



Bevington: a production-capacity cap

head of the environment section of the Dutch Foundation for Nature & the Environment in Utrecht, "It is usually the U.K., France, and Italy against any serious [environmental control] measures. Now the U.K. is starting to change its position, with France and Italy still against [CFC] controls." In EEC negotiations on CFC controls, Italy is usually represented by a CFC producer, and France tries to protect its cosmetics industry, explains Reijnders.

He also points out that the most serious resistance to CFC controls comes not from the producers, but from users—from the manufacturers of cosmetics and foams, and from the refrigeration industry. "These are more important politically," he says.

The State Department's Benedick concurs. "The big question mark is how European industries react. Industries have more political power and control in Europe because there are no counterbalancing forces there." The environmental groups and the press have not been so interested in the ozone issue as they have been in control of acid rain. Moreover, "Many European delegations send only industry people to [UNEP] meetings," Benedick explains.

The U.S. has decided on its negotiating strategy for next month's UNEP meeting in Geneva. It will seek a near-term global production cap on CFC-11, -12, and -113, and Halon-1211 and -1301 "at or near current levels," and a gradual phase-out of these ozone-depleting chemicals over the longer term. The intent is to lower emission rates, but how great a cutback is needed "has not yet been decided," Benedick says.

EPA's schedule of arriving at a domestic regulatory position on CFCs is unchanged by the U.S. international posture. (On May 1, 1987, EPA will issue its regulatory proposals; and in November, the final regulations, if any, will be promulgated.) "The State Department's Geneva proposal doesn't affect us," says Stephen R. Seidel, a senior analyst in EPA's office of strategic studies. "It would be our position only if the rest of the countries agreed to it," he adds.

The Changing Atmosphere

However, more than three dozen other nations are involved in these UNEP negotiations on a global ozone protection protocol. And many are likely to offer other proposals.

Outcome of negotiation doubtful

There is still much uncertainty about what the outcome of the ozone protection protocol process will be. "I remain doubtful that the process will produce a result adequate to meet short-term [U.S.] political considerations," Miller says.

Edward J. Woodhouse, who teaches political science at Rensselaer Polytechnic Institute and who recently coauthored "Averting Catastrophe: Strategies for Regulating Risky Technologies," agrees. He is pessimistic about "a concerted strategy—like a monetary conference—being developed for protection of stratospheric ozone." The Organization for Economic Cooperation & Development countries, which produce and use 80% of the world's CFCs, will take action only if the science is compelling, he says.

Some of the science being sorted out points strongly to the bridging role CFCs play in both ozone depletion and climate warming. At a pivotal scientific meeting held last year in Villach, Austria, scientists concluded that CFCs as a group may, within the next few decades, become the second most important greenhouse gas after carbon dioxide if no preventive steps are taken. (Global CFC atmospheric levels are growing at about 5 to 7% a year, and the compounds have long-lived residence times in the troposphere.) The scientists also concluded that CFC control was easier than limiting or reducing carbon dioxide emissions.

"If we can set up a protocol that is designed to provide an intelligent path for global airshed management—the apportionment of CFC emission limits equitably among the various countries—then we will be in a position to use that experience to draw a later agreement on greenhouse gases. CFC control provides a relatively simple opportunity to learn," Michael Oppenheimer, a senior scientist with the Environmental Defense Fund, believes. □



The overwhelming consensus of scientists studying climate change is that the chemical forces that will alter climate during the next century are starting to do their damage now. Pressure thus is growing on the U.S. and foreign governments to begin taking immediate steps to avert catastrophe or at least establish policies of adaptation to the inevitable changes.

"These are no longer just science issues," declares Sen. John H. Chafee (R.-R.I.), "they are policy issues." Chafee heads a Senate environment subcommittee that held hearings on climate change and threats to the ozone layer last June.

Two months later, in August, the Senate ratified the convention for the protection of the stratospheric ozone layer. In further action, Congress appropriated an extra several million dollars to the Environmental Protection Agency for upgraded programs and research on the chemical threat to climate and the atmosphere. And another bill requiring the President to plan an International Year of the Greenhouse Effect passed. Other, more sweeping, measures were introduced.

Activists believe policy action can start to be taken now. The federal government, for example, can help coastal cities begin factoring into their 30- to 50-year public works plans the likelihood of a sea-level rise of up to 2 feet by 2050. It can rethink its own water resource pro-

grams for a time when rainfall patterns change drastically. Department of Energy analysts could devise alternatives to the burning of fossil fuels as energy sources. Research could be sponsored on new process technology aimed at further energy efficiency and reduced waste products. In the larger policy spectrum, the Administration could begin requiring that environmental impact statements for planned construction projects include climate scenarios.

This is policy making on a grand scale. And it isn't easy. First of all, the issue is international. Alleviating disaster can come about only if enough countries act. Second, any restrictions put on industrial activities will be expensive and politically hard to achieve. Third, it isn't one gas that affects global dynamics. It is predominantly four: chlorofluorocarbons (CFCs), carbon dioxide, nitrous oxide, and methane. Each gas has its "sociology"; each its economics; and therefore each its regulatory complexities.

Further, scientists don't yet know region by region what the changes will be. Regional impacts projected by the major computer models all differ. And finally, the Administration does not yet have a climate change policy. What it does have is a bedazzling collage of programs with specific, interrelated titles.

The policy debate

Pressures to establish policy—sets of goals with steps to achieve them—have their origin, naturally, in various environmental groups. A major actor is the Natural Resources Defense Council, which successfully won its suit against EPA to force the agency to move more quickly in regulating CFCs. The World Resources Institute has taken an overall policy lead by issuing studies on consequences and laying out policy options. The Worldwatch Institute has done continuing studies geared toward explaining the ecological consequences of industrialization. The Conservation Foundation is preparing ambitious policy documents of its own. The Environmental Defense Fund and Sierra Club both have active programs of education, information, and public policy.

Controlling carbon dioxide: the view from Europe

So far, there has been little official activity in Europe addressing the specific question of carbon dioxide emissions and global warming. But that situation is beginning to change.

The European Parliament—legislative advisory arm of the European Economic Community—recently issued a report on research and energy policy measures to deal with the “rising concentration of carbon dioxide in the atmosphere.” The report essentially recommended that because some warming effects were in the offing by the end of the century, cuts in carbon dioxide emissions of at least 2% a year should go into effect immediately.

This led the parliament to adopt a resolution calling for reduction of carbon dioxide emissions. It said major means of reduction should be energy conservation measures. It called, too, for stepped-up programs of reforestation in Third World countries, as well as programs to give those countries access to advanced energy know-how.

The resolution is one small step forward in a coordinated European policy toward carbon dioxide regulation. It will go to the Council of Ministers of EEC, which will decide whether to put it into effect. Once in effect, the EEC nations would be bound to enforce it.

So while scientists urge more study, the environmental community is pushing for action. Gus Speth, president of the World Resources Institute, states the basic philosophy. “When dealing with risks that are grave but cumulative and irreversible, uncertainty is a strong argument in favor of action. We must take whatever steps are feasible as soon as possible to reduce the dangers.”

EPA Administrator Lee M. Thomas agrees in part. “We’re talking about pretty substantial global changes,” he says. “So here at EPA we’re trying to develop a general scientific consensus on the causes and effects and then a general consensus on solutions. This is something that’s going to take some time. We’re working to participate better in interagency discussions and be more formal in the way we’re

“Interest in the greenhouse effect is picking up now,” says Lucas Reijnders, head of the Environmental Protection & Resources Group of the Dutch Foundation for Nature & the Environment, in Utrecht. “The current coalition government [in the Netherlands] wants to put more energy into the carbon dioxide problem.”

Such interest is triggered by the tendency of the Dutch to equate the greenhouse effect with rising sea levels, a matter of major concern to this low-lying country. But complicating the issue, Reijnders says, is overwhelming popular opposition to nuclear energy, a major substitute for fossil fuel power.

“Other countries,” says Reijnders, “don’t feel [the greenhouse effect] is much of a political issue. And we want to change this.” To that end, Reijnders is spearheading a major conference on the greenhouse effect in Europe at the end of next year.

Whether his and related environmental groups really can change the views of the other European countries is problematical. Coal is an important fuel in Europe—more so after the disaster at Chernobyl. So the trend is really away from any controls on fossil fuels. The Labour and Conservative

parties in the U.K., for example, have been debating energy options, but in economic terms, rather than from considerations of the greenhouse effect.

Three years ago, Britain’s Central Electricity Generating Board commissioned a study into “man-made carbon dioxide and climatic change.” But the upshot was mainly a list of energy conservation measures that could be employed to reduce future effects.

In Eastern Europe, whose energy policies Reijnders has been tracking, “there simply are much more pressing problems than carbon dioxide,” he says. “In Poland and Czechoslovakia, for example, coal dust is the main concern as an environmental threat. And we all get a feeling that the U.S.S.R. would not mind a warming up anyway. Awareness will come, but not for a time.”

European researchers and environmentalists are aware that agriculture-based methane and nitrogen oxides also contribute to climate warming or ozone depletion. But work on controlling them is nonexistent. “These gases merit more study, especially in the percentage of their impact on the atmosphere, but it is doubtful that we could bring their levels down 30 to 40%,” Reijnders says.

assessing both the scientific and policy issues associated with climate change.”

Thomas believes prevention is the policy course of choice. “I can understand why people say adaptation is the most practical tack to take, but I’m not prepared to make such a statement,” he says. “Over the next several years we could begin to know that the environmental effects could be too severe. I think we’re going to work both sides simultaneously. We’re going to look at our options as far as control is concerned, on the variety of gases we know of. At the same time we’re going to work more aggressively on the effects side. In the meantime I have a prevention bias.”

But Alan Hecht, head of the National Climate Program at the National Oceanic & Atmospheric Administration, appears to lean toward

a policy of adaptation. “It’s hard to conceive that this thing can be controlled globally,” he says. “I think we’ll adapt one way or another. What it really all comes down to is economics—shifting the burdens and the impact so that the fewest people are hurt.”

Pace in Congress picks up

Congress is beginning to quicken its pace in dealing with the legislative aspects of both the ozone and greenhouse issues. There will be some preparatory action when the new Congress assembles in January. Then all the relevant bills introduced in the last Congress will be reintroduced. And, at the same time, the National Academy of Sciences will brief Congress on climate change to give legislators a strong grounding in the scientific issues. Soon after, various commit-

The Changing Atmosphere

tees will begin oversight hearings.

Congress began to stir on global climate as it was winding up its work last month. In last-minute action, an amendment was added to the National Science Foundation's appropriations requiring the President to plan for a 1991 International Year of the Greenhouse Effect. It directed the President to give Congress a progress report on those plans no later than next Aug. 1. The White House Office of Science & Technology Policy will be working on the President's response. In other action, EPA received \$5.6 million to conduct research on ozone depletion and climate change, an increase of \$1.75 million over fiscal 1986.

In the House, Rep. Bill Richardson (D.-N.M.) introduced the Stratospheric Ozone & Climate Protection Act of 1986. The bill—H.R. 5737—essentially says that if the Geneva ozone protection protocol negotiations that begin Dec. 1 are not moving fast enough, the House will consider legislation mandating phaseout over five years of at least CFCs and bromine-containing compounds. U.S. production of the man-made compounds listed as climate-changing and ozone-depleting would be cut 50% within two and a half years of being listed, and phased out entirely over five years—unless EPA hastens reduction through rule making. The bill also would ban imports of listed compounds or products made from or with them, unless EPA certifies that the exporting country is in a phaseout program with a pace equivalent to that of the U.S.

In the Senate, Joseph R. Biden Jr. (D.-Del.), Claiborne Pell (D.-R.I.), and Charles McC. Mathias Jr. (R.-Md.) introduced the Global Climate Protection Act. That bill would create an executive branch task force on the global climate, chaired by the Secretary of State with the head of EPA serving as vice chairman and executive director of research. The task force would develop in a year a governmentwide strategy to assess "the threat raised by global warming and to respond to that threat by national and multinational means." Three months after the task force's report, the President would

submit the strategy to Congress with specific recommendations for further legislation.

Under the bill, the President also would appoint an ambassador-at-large to coordinate and lead U.S. participation in the International Geosphere & Biosphere Program, a newly approved international attempt to understand through satellite monitoring, supercomputer technology, and Earth-based research the dynamics of atmospheric forces.

"One duty of this ambassador," says Biden, "would be to seek early designation within the United Nations system of an International Year of Global Climate Protection. The legislation also calls on the President to put global warming on the U.S.-Soviet policy agenda."

Whether any new legislation will be successful is problematical. What is significant is that only a handful of Senators and Congressmen seem concerned about the issues. The overwhelming numbers of legislators from the Gulf and lower Atlantic coastal states and from the farm belt—areas that could be hardest hit by droughts and a sea-level rise—have been silent. There is far less than a critical Congressional mass over the issue, and it would probably take imminent catastrophe to create it.

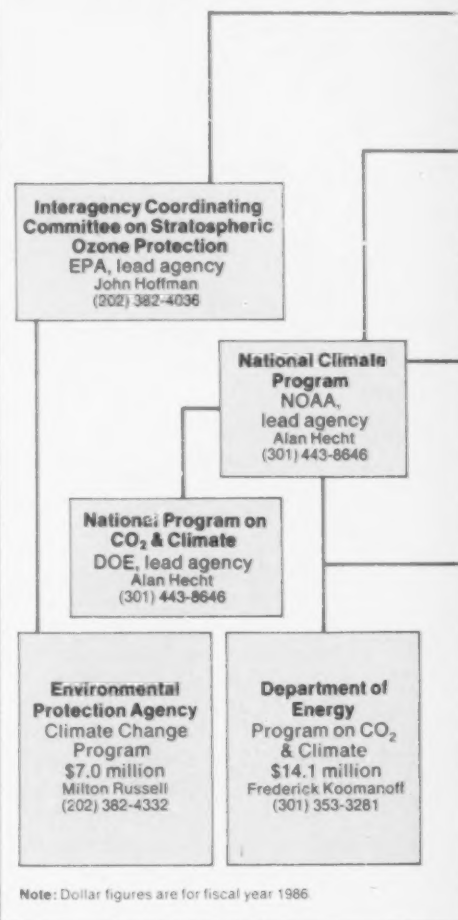
Sen. Albert Gore Jr. (D.-Tenn.), who spearheaded the idea of the International Year of the Greenhouse Effect, thinks that time is near, especially if extremes in local weather patterns continue to occur. "Because of three hot years in a row," he says, "the drought caused an economic catastrophe in the Southeast this year," he says. "These changes, which appear to be small when you look at the numbers, have tremendous economic effects and will have tremendous political effects."

Collage of climate studies

It would be reassuring to report that the federal government is poised and organized to deal with the policy impacts of climate change. But though the government is beginning to try to put its climate change house in order, that unfortunately isn't the case.

One key observer of the whole climate change issue is David Burns,

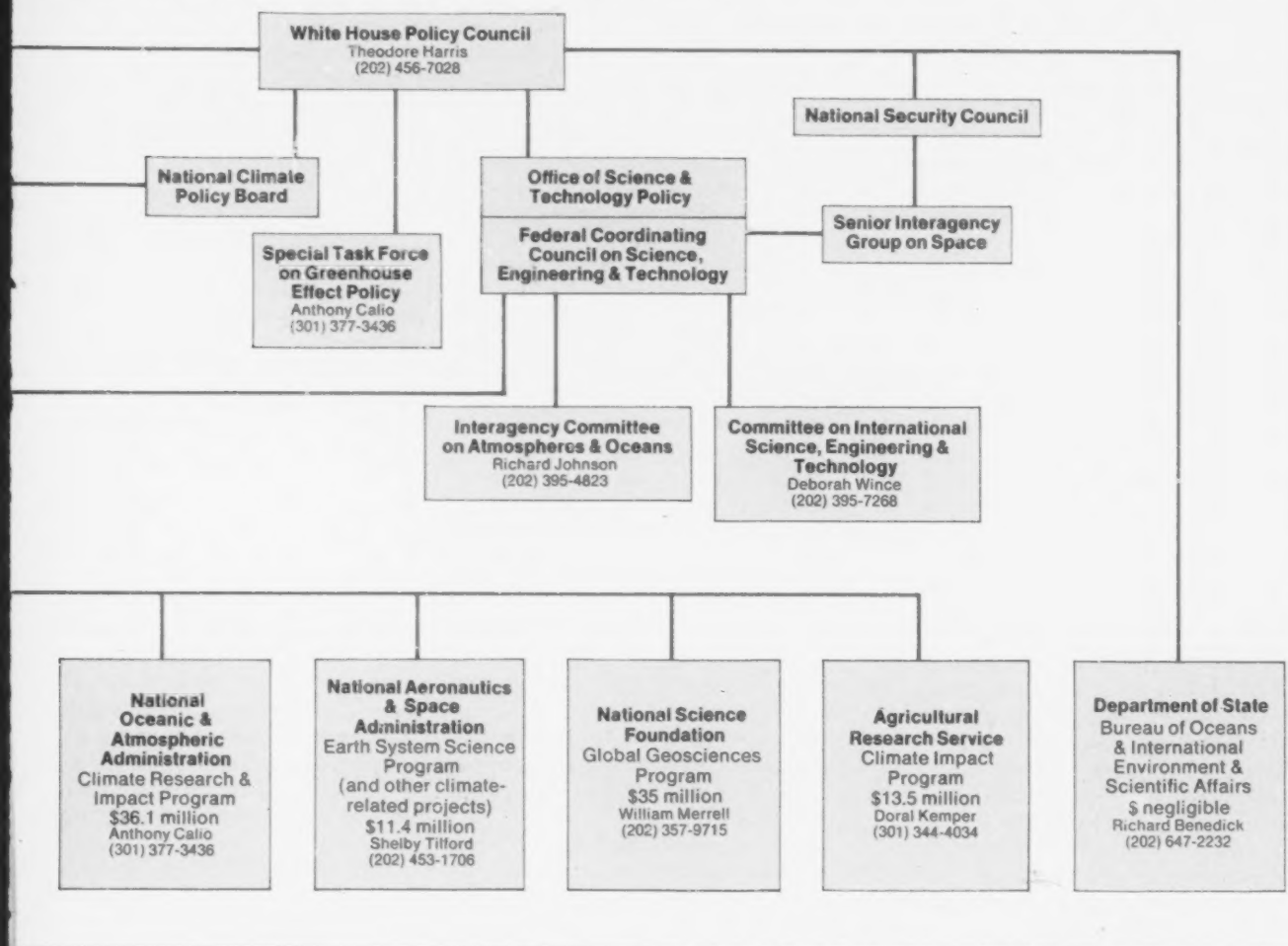
U.S. climate change research



who heads a 10-year-old climate variability program at the American Association for the Advancement of Science. "I've been working on the climate change issue for several years now, and I still don't have a clear perception of where the authority lies. There's a lot of tugging and pulling going on."

The problem is coordination. There do appear to be more than enough agencies with specific missions to do specific things. There exists a National Climate Program (NCP) run by NOAA in the Commerce Department. It is the result of legislation promoted by Rep. George E. Brown Jr. (D.-Calif.) for an interagency program to oversee climatological research across several agencies. NCP covers a whole range of climatological issues, from research needs in the forecasting of

and policy programs are separate and uncoordinated



tornadoes, hurricanes, and floods, to gaps in the modeling of climate trends. NCP in turn has a policy counterpart in the form of the National Climate Policy Board, which meets to make recommendations on national policies underscored by climate and weather.

In addition, there is an interagency group on the ozone layer coordinated by EPA, from a policy planning and evaluation office headed by John Hoffman. This group's efforts feed into the climate change issue because of the role CFCs play in climate warming. For climate change induced by carbon dioxide, however, DOE is the lead agency. NASA designs and launches the satellites that monitor the chemistry at various altitudes, longitudes, and latitudes, besides conducting state-of-the-art modeling work on climate

trends. NSF supports basic research on weather and climate dynamics.

But too many agencies speak only for themselves. "The issue of who speaks for whom is an important one because an orderly process needs to be developed," says NOAA's Hecht. "The CFC/ozone issue is in good shape," he says. "There is a lead agency—EPA. A timetable of meetings has been scheduled nationally and internationally to establish policies for the control of CFCs and other ozone-depleting chemicals. As a result there is a process under way to reach a U.S. position to present internationally. To some extent there will be controversies over to what degree industry regulates itself, and to what degree government must regulate. The greenhouse gas issue is more complicated."

Perhaps the biggest need is resolution of the continuing squabble between EPA and DOE over which agency should set the research agenda for studying climate change. There is a strife-packed history behind the current impasse.

Conflicts began in 1983 when EPA released two reports on climate change—one on warming trends, the other on sea-level effects. The first was released to the public a few days before the National Academy of Sciences issued its own report on global warming. The academy persuaded then Presidential science adviser George A. Keyworth II to issue a formal reprimand to the EPA researchers for making what the academy panel and DOE felt were unsubstantiated conclusions.

Up to that time, DOE was the leading government voice on cli-

The Changing Atmosphere

mate warming through its program on carbon dioxide/climate research. EPA's two reports, besides shocking DOE by their sudden emergence, created enormous media attention. They warned not only of coming changes but that the warming issue was not so simple as DOE's carbon dioxide-focused research program implied. As the EPA documents reported, not only carbon dioxide but three other gases were contributing to the warming. DOE's program was suddenly inferred to be too narrow in scope. DOE thus saw the EPA reports as the opening salvos of a power grab.

A source in NOAA claims the solution could be simple. "The best advice I'd give EPA," he says, "is to concentrate on its charter and work very closely with NASA, DOE, etc., to explore the policy and impact issues. They shouldn't do climate research. They should build bridges so we can all work as a team. EPA has done a lot of things people in the other agencies were not made aware of. The worst thing that could happen is for EPA to isolate itself."

"I'd suggest," says an EPA source, "that it's the DOE program that's the isolated one. We are the ones sitting in the middle of the issue. It's unfair to be putting us on the extreme end. There aren't many reasons why the warming issue should be in DOE anyway. The issue was originally construed as an energy policy problem, and there was fear that it would be handled inappropriately by another agency. I don't think that's the case any more. We are not going to tear down all the fossil fuel plants in the country. That's crazy. I was glad to see Sen. Chafee actually admit in the last session of Congress that there could come a time when we may need to consider the need for more nuclear power." He adds that if he were a member of DOE's upper management, he would try to use this new information on other gases to DOE's advantage, instead of fighting the trend.

NOAA, too, would like a stronger role in setting research policy. But it has had to be shy about showing any muscle. NOAA is a weak agency. During almost every budget cycle, the Office of Management &

Program aims at developing global atmosphere research

The problems of climate change are global, and if countries are to mount a truly systematic approach to understanding how industrial activities induce such changes, a strong international research program is needed. This is beginning through a new effort known as the International Geosphere & Biosphere Program, coordinated by the International Council of Scientific Unions, which approved the massive venture in September. The National Academy of Sciences is the U.S. secretariat for IGBP, and the federal government is in the process of establishing an interagency structure for coordinating U.S. involvement.

"IGBP," says an ICSU briefing document, "will be a carefully designed program of research directed at providing the information we need to assess the future of Earth in the next 100 years, with an emphasis on processes that change on time scales of decades to centuries. It will be a program of basic research with almost immediate practical applications in the management of resources at national and international levels and as a means of improving the reliability of warnings of global change of significance to our environment and to humankind."

Two technical developments have made such an undertaking possible: the satellite and the supercomputer. With satellites, scientists now can view a vast array of physical, chemical, and biological changes in global dynamics. And the computer can integrate them and develop patterns and thus predictability. But the data problems are massive. The National Aeronautics & Space Administration, which will feed data to IGBP, is up to five years behind in translating from its tapes the digital information on ocean winds and waves, cloud movement, and chemical transformations in the upper atmosphere obtained by satellite monitoring.

"Over the next decade the flow of data will increase from thousands of observations each day to many millions of observations," says an earth sciences policy report produced by the Office of Science & Technology Policy in 1985. "Digital data rates soon will increase from 100 billion bits per day to over 10 trillion bits per day. Some capability for sorting that data for impor-

tant information and managing the data streams is essential. Proper handling of all these data at affordable costs is probably the biggest technological challenge to be faced in the program."

Putting data management problems aside, there still remains a slight flaw in the IGBP research framework. IGBP is primarily a physical science program. Atmospheric scientists and oceanographers have been working together for years on various interdisciplinary projects. Biologists, on the other hand, have not. Only a handful of ecologists have much experience working with each other and their physical science counterparts.

"It's true that the biological/ecological aspects of IGBP are not well organized. It's hard to get a handle on them," says NAS's John Perry. There are only a few ecologists who study large geographic areas. And they have no research center on the scale of the Boulder, Colo., National Center for Atmospheric Research (NCAR). "You'd think the biologists would be well out front on this [issue of climate change]. But that isn't the way biology works," Perry explains.

Social science and the almost forgotten science of geography, too, have been excluded in government climate change programs, especially in the Department of Energy's programs, Perry says. The social sciences will almost certainly have to be included because IGBP's objectives stress human impact, Perry points out. As for geography, one source says, researchers in that field "are always off huddling by themselves."

William Merrell, assistant director for geosciences at the National Science Foundation, says he isn't too worried about any biology gap in either IGBP or NSF's global geosciences program. NSF's directorate in biological and behavioral sciences is slowly folding some of its programs into NSF's global geosciences program, and that in turn will fold into IGBP, he says.

Furthermore, NSF's assistant director for biological and behavioral sciences, Frank Harris, has made many trips to NCAR, which NSF funds, to begin the interaction between the physical and biological scientists. "These visits will change the way ecologists think about global systems," says Merrell.

Budget has tried to eliminate it by selling off to the private sector its satellite monitoring and weather forecasting functions. Each time NOAA has fought off such attempts. Focused mainly on its own survival, it was never in any position to play interagency turf politics.

NOAA is indeed a key agency if only for the simple fact that its main mission is to do research on weather and climate and provide forecasts and warnings. Its mission is clear. It has no soaring ambitions except to increase its research program. Its biggest problem is maintaining its mission in the face of attempts by some quarters at NASA to grab away important meteorological research. That conflict, although extremely nettlesome to NOAA, is, however, nowhere so severe as the trench warfare between EPA and DOE.

Coordination to be worked out

By the end of the year, the White House Domestic Policy Council, through its working group on environment and natural resources, is expected to produce a position paper on how the agencies should be organized to deal with climate change as a policy issue. The council has appointed NOAA's Administrator, Anthony Calio, to head a task force to determine Administration policy on the greenhouse issue.

"We're trying to come to a common Administration position on greenhouse," says a council source. "A number of us believe there is a need for some sort of guidance that can be given to all the agencies concerned with global warming. We will try to arrive at a government position, make linkages between economics and policy, include agency coordination, and decide on levels of agency funding over what periods. We then will give a briefing to the department Secretaries."

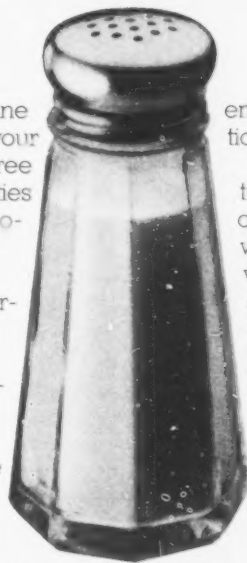
The council also is trying to coordinate the U.S. role in the new International Geosphere & Biosphere Program with NASA's earth systems science program and with NSF's Global Geosciences Program. "There is obviously a tug of war going on among NASA, NOAA, and NSF as to who is the biggest kid on the block," says the source. "But there's a role for everybody."

"I don't think you'll see a czar with respect to global change," says the source. "We have several layers of bureaucratic systems that can handle the coordination problems. The agency with the strongest voice coming out of all this will be DOE. It will be a reluctant bride, but energy production still seems to be the critical issue in

warming," says the council source. In any case, interagency coordination draws cynical commentary these days. "Right now coordination is about as nice a job as shoveling garbage," says one atmospheric sciences official. "The agencies come together only when they're desperate for money."

Meanwhile, EPA is taking its cli-

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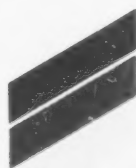


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mate change role seriously. Most of its research work is being done in its program planning and evaluation office, and less than a dozen staff persons are working full time on it. However, with the extra \$5.6 million given to it by Congress to pursue risk assessment and risk management studies of global warming, the agency is ready to go.

"The actors are in place," says Thomas, "and with the additional money and resources we just got, we're going to see EPA in the course of this year not only better coordinated but with a better focus on its effects work. Some of that already has come out of EPA—like our sea-level rise study. We asked what effect [climate warming] would have on coastal wetlands. We found that the effects could be pretty dramatic with fairly small sea-level rises. We think effects work is important because it is a frame of reference for us to consider the impact environmentally in this issue and frames the kind of options a policy maker may want to consider."

EPA's big difficulty, says Thomas, is in the connection between CFCs and the greenhouse effect. "If you try to relate CFC regulations to greenhouse, you may have to make more stringent decisions," he explains. "We need to look at whether we want to include both effects [ozone depletion and climate warming] and set up a time frame for reviewing them over the next couple of years. Right now we don't know how we're going to fold them into the CFC issue. But greenhouse is going to be a factor in this."

EPA will step up its review of the science and keep up to date on findings, Thomas says. He believes a lot more research is needed, especially on the effects of warming. "This leads us to ask what kind of adaptation will be required if there's warming in certain parts of the world, what steps might be needed to reverse it. Some of that [research] is going to be done here [at EPA]." Still, he adds, "A lot of work around the world needs to be coordinated, and UNEP is a good center for much of that coordination."

"But collaboration is important among EPA, DOE, and the rest of the agencies. We need to be sure



Merrell: tie science to policy studies

we can participate actively in framing some of the policy questions that must go to the science agencies. I realize there is some debate over whether you should do effects work before you are fully convinced you have an effect to deal with. But I see the whole process going along parallel sets of tracks."

Plus tracks lining the tracks. "The key to it all," says NSF's assistant director for geosciences William Merrell, "is to be sure we tie the results from projects in the earth and atmospheric sciences to policy studies as rapidly as we can."

Where things are headed

Everyone involved with global change can agree on one thing: Industrialization is changing the physical atmosphere around Earth and thus every living thing on it. Research is needed to understand those changes as the gases build, converge, and interact. Policy choices will have to be made—perhaps with increasing frequency. So policy work will have to proceed in the face of scientific uncertainties.

That is what a veteran participant in international science and its policies underscored at a meeting earlier this month at Columbia University. He is Thomas Malone, formerly foreign secretary at NAS, official in the International Council of Scientific Unions, and now a professor at St. Joseph's College in Philadelphia.

"The essence of all of this," said



Thomas: better focus on effects work

Malone, "is that the life portion and the physical portion of these problems are one integrated system. And this poses a tremendous challenge to the life sciences and the physical sciences to get together in a way

that's never been accomplished before."

"It is not time to begin policy decisions," Malone added. "But it is time to lay the intellectual foundation for them. We have to do risk assessments. The kind of extreme effects EPA is identifying is precisely what should be done. It's not whether the global temperatures will rise 2 to 4°. It's what is the chance of an extreme event happening. It's the small chance-large consequence that we should be addressing."

Malone suggested that politicians should be brought into what amounts to policy games so they can be given a deeper understanding of the scientific uncertainties. Such games, involving what he called "surprise-rich scenarios," could supply political officials with insight into the consequences of their political decisions. He said the games should begin immediately.

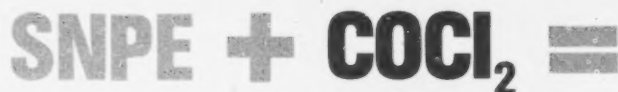
EPA's Thomas agrees that a whole



Hecht: adapt one way or another

new era has arrived in environmental regulation and the policies needed to carry it out. "The interaction between us and other countries is more and more a direction we're taking," he says. "We're going

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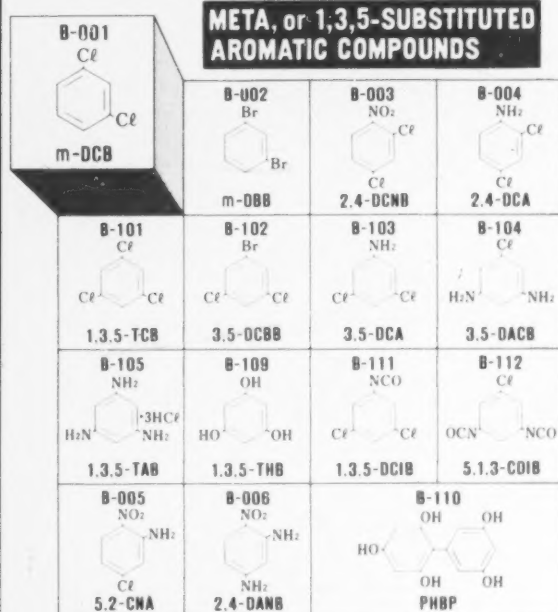
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The Changing Atmosphere

to see more and more of such issues. You can't take domestic regulatory action without affecting the economies of other countries."

Coordination is still the key, however. "Most so-called policy makers in Washington are pulling on disconnected levers," says Jesse Ausable, director of projects at the National Academy of Engineering. "We might wish that we could really change energy policy, but it's not so clear we can. All of us would agree that our bias could be to reduce emissions. But I just really wonder whether any sweep of policies that governments can enact will really make much difference. Even the best-meaning policies may be overwhelmed by factors of productivity growth, population growth, or the impossibility of developing solar or nuclear options. The question is how realistic these proposals are."

Maybe so, maybe not. Maybe the more basic question is whether, as Gore indicates, the prevention/adaptation options suggested are really too modest in the face of what lies ahead. The Ausables of the policy world believe the industrial countries possess the technologies to adapt. If so, it would follow that they also possess the technologies and policy capabilities to prevent.

The economic system has been adapting to the environmental era for two decades now. In that time the bugaboo of regulation stultifying growth of the gross national product has never been demonstrated. The two systems have shown they can live together—indeed, depend on one another. When a planet's life support system seems to be at stake, and when there does appear to be enough time to plan ahead, wouldn't economic caution amount to a silly luxury? □

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Status of chemical R&D in the U.K.
Page 22

DECEMBER 1, 1986 12/1/86

A1250-1

CHEMICAL & ENGINEERING

NEWS

SRI ALUMINA 20814
BETHESDA MD

AIDS

Better understanding
of complex virus emerges
Page 7

News of the Week

■ In Bhopal legal battle, India attempts to freeze Union Carbide's assets until extent of liability is determined. **Page 4**

■ Chemical productivity increases in the third quarter as a result of cost-cutting measures. **Page 5**

■ Caltech radiotelescope, which extends detection range, is ready to begin operating at Mauna Kea, Hawaii. **Page 5**

■ New electrical method can detect and locate leaks in hazardous waste impoundment liners. **Page 6**

■ EPA issues final guidelines for emissions-trading policy to meet air pollution requirements under Clean Air Act. **Page 6**

Cover: Multinucleated giant cell infected with human immunodeficiency virus, the AIDS-causing agent. Photo courtesy of National Institute of Allergy & Infectious Diseases and *Science* [233, 1089 (1986)]

Letters **2**

Concentrates

Business **13**

Government **18**

Science/Technology **21**

The Departments

ACS Comment **27**

ACS News **28**

Meetings **38**

Newscripts **40**

Business

Enrichment of uranium into fuel-grade material is a government monopoly in the U.S., but private enterprise is seeking to enter the market despite past failures. **Page 14**

International Business

Pemex, Mexico's state-owned oil company, plans to spend \$2.5 billion over next six years on new petrochemical plants in attempt to reduce petrochemical import bill. **Page 16**

Government

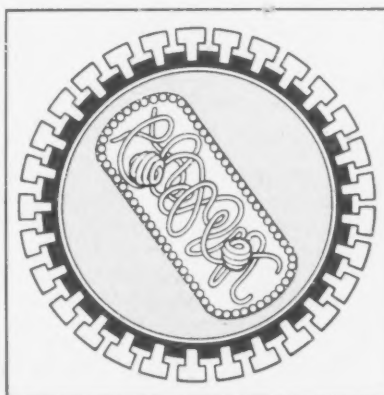
House report on confusing biotechnology regulations recommends retaining current laws, but urges more research to fill information gaps and clearer definition of key terms. **Page 19**

Science

Status of chemical R&D in U.K. is subject of three reports, one of which focuses on need to assess priority areas, the other two compare funding and quality of British science with those in other countries. **Page 22**

Books

According to the authors of "Beyond Oil," energy consumption—not price, capital, and labor—is the major driving force behind the gross national product. **Page 25**



News Focus

AIDS researchers are making progress in delineating the virus that causes AIDS and in their studies of the effects of infection. **Page 7**

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LETTERS

Special appreciation

SIR: This is a note of special appreciation to the hundreds of ACS members who worked on my behalf in the recent ACS presidential campaign and to the more than 19,000 ACS members who supported my candidacy. Your help and support are highly valued and appreciated.

The active, positive campaign by all candidates in the election and the excellent voter participation were, I think, healthy for the society. My heartiest congratulations to Ernest Eliel for a very fine campaign.

The untimely passing of Robert Brasted in early October was a sad loss for us all. His leadership will be missed on the board.

ACS has grown significantly in programs and prestige over the past several years. I solicit member comment and input as we position ourselves to address the many challenges facing chemists and chemistry.

Gordon L. Nelson

ACS President-Elect

Chairman, Polymer Science

University of Southern Mississippi

Hattiesburg

Sodium as a coolant

SIR: In your June 30 issue (page 18) there appeared an article entitled "New Era of Inherently Safe Nuclear Reactor Technology Nears," by Joseph Haggin. In a subsequent letter to the editor, "Nuclear reactor safety," (Sept. 1, page 3) James D. Bushnell raised a number of concerns. This letter specifically addresses his concerns about sodium as a coolant in a liquid-metal cooled reactor (LMR) and the implications of the EBR-II Inherent Safety Demonstration Test.

In an LMR, sodium is used as a coolant because of its excellent nuclear, physical, and chemical properties. Its high boiling point and excellent compatibility with stainless steel make it possible to (1) design an extremely reliable primary vessel to contain the reactor and the sodium coolant and (2) design the reactor system to be inherently or passively safe for a leak of sodium out of the primary vessel.

In the pool-type design, now largely favored in the rest of the world as well as in the U.S., the highly radioactive reactor system is immersed in a large pool of sodium that is contained in a primary vessel. The system operates at near atmospheric pressure under a blanket of inert argon gas. There are no penetrations in this vessel below the level of sodium. Although stresses in this vessel

that could lead to leaks are low, it is contained within a second vessel—the guard vessel. The intervening space between the vessels contains sodium leak detectors and is filled with argon gas. Thus if there were a leak, the sodium would not react with the inert argon atmosphere, and would be detected. If no action were taken, the leaking sodium would fill the space between the primary and guard vessels until its level equilibrated with the level of sodium in the primary vessel. The geometry of the primary and guard vessels is established so that the core is kept covered and can be cooled by natural convection. Thus the system is inherently safe for leaks in the primary tank.

Sodium is also used as a coolant for the intermediate system that transports heat from the primary tank to the nonradioactive steam generators. Bushnell correctly observes that a leak in the steam generator can cause problems, owing to Na-H₂O reaction. This is, in fact, the major real problem area in the design of an LMR power plant. Although EBR-II has never experienced a water-to-sodium leak in more than 22 years of sodium-heated steam generator operation, such leaks have occurred in other plants. None have posed a risk to public safety, since no highly radioactive primary sodium is involved. Indeed, this concern is the major reason for using the intermediate heat transfer system. Since the Na-H₂O reaction takes place between the secondary and steam systems, and the primary system is isolated from these systems, concerns such as "frothing over of the sodium pool, disruption of the pool convection currents," are not realistic.

The use of the large pool of primary sodium as a heat sink during loss of external cooling is an advantage, as Bushnell notes. He then goes on to say "that if the core continued to generate heat at design rate, the sodium would be heated from 650 °F to its boiling point in something like a half hour. . . ." But, as your June 30 article pointed out, in a properly designed, metal-fueled LMR the core would not continue to generate heat at design rate. In the EBR-II loss-of-heat-

Correction

• Nov. 10, page 14: Du Pont's earnings of \$322.0 million for third-quarter 1986 were down 7.2% from the year before. Profit margin for third-quarter 1985 was 4.8%.

Mexico's Pemex Continues Building Petrochemical Plants

State-owned oil giant will spend \$2.5 billion on petrochemicals over next six years in spite of country's economic problems

Mexico's severe economic problems, its huge foreign debt, and shortage of capital has put a crimp in Pemex's (Petróleos Mexicanos) petrochemical investment plans over the past few years. Yet, even after cutting back on some previously announced projects, the state-owned oil company still estimates that it will spend about \$2.5 billion over the next six years for new petrochemical plants.

Antonio Juarez Alvarado, assistant director of petrochemical commercial policy, says that Pemex should have little trouble getting the money. The government, he says, is putting renewed emphasis on certain priority industries. Petrochemicals is one of those industries.

Still, companies in the secondary, or downstream, segment of Mexico's chemical industry that rely on Pemex for their raw materials are taking a wait-and-see attitude. Pemex has a long history of failing to meet demand for its basic petrochemicals. It also has a reputation for not bringing its plants on stream as scheduled.

Shortages are particularly acute in aromatics. And it's not simply a question of inadequate capacity. Pemex hasn't been able to produce as much as it should from existing plants. Through the first nine months of this year, for instance, Pemex produced only 62% of its planned output of xylenes. For benzene, the figure was 88%.

When he recently announced Pemex's petrochemical investment plans, Mario Ramon Beteta, the company's general director, conceded Pemex's poor performance record in the past. "A lot of time has gone by between the time a plant is on stream and when it reaches 100% of capacity," he says. But he promises that Pemex will reduce that time in the future.

Pemex's new petrochemical investment program is the result of a new study estimating Mexico's future basic petrochemical requirements. The proposed schedule, Beteta says, can be slowed or accelerated, depending upon Mexico's general economic condition and the raw material demands of the secondary petrochemical industry.

High on Pemex's priority list is the completion of its Morelos petrochemical complex. Almost, but not quite, a duplicate of the recently completed complex at La Cangrejera, Morelos will sport a 500,000 metric-ton-per-year ethylene unit and a 350,000-metric-ton propylene plant. The ethylene unit is expected to be operating in early 1988; the propylene plant is due on stream later that year.

Morelos will play an important role in reducing Mexico's trade deficit in olefins derivatives. In 1988, Pemex plans to have on stream there a 200,000 metric-ton-per-year ethylene oxide plant. Last year, Mexico imported more than 48,000 metric tons of ethylene oxide.

The country's first polypropylene plant—a 100,000-metric-ton unit—also will go on stream at Morelos in early 1989, making it possible to reduce its import bill \$80 million per year. Pemex also plans to continue building plants to produce butadiene (100,000 metric tons a year), acrylonitrile (50,000 metric tons),

and isopropyl alcohol (75,000 metric tons) at Morelos. These units will come on stream between 1988 and 1991.

In addition, Morelos will contain Mexico's second high-density polyethylene plant—a 100,000 metric-

Pemex's petrochemical program to add lot of new capacity

Location/product	Planned petrochemical projects	
	Capacity (thousands of metric tons per year)	Completion date
Morelos		
Ethylene	500	1988
Propylene	350	1988
Ethylene oxide	200	1988
Polypropylene	100	1989
Butadiene	100	a
Acrylonitrile	50	a
Isopropyl alcohol	75	a
Acetaldehyde	150	1989
Polyethylene, high density	100	1988
Polyethylene, linear low density	80	1990
Pajaritos		
Vinyl chloride	200 to 300	b
Salina Cruz		
Benzene	275	b
Toluene	120	b
o-Xylene	30	b
p-Xylene	200	b
Heavy aromatics	29	b
San Martin		
Texmelucan		
Acrylonitrile	50	1987
Ciudad Madero		
Cumene ^c	20	b
MTBE	30	b
Salamanca		
Olefins ^d	50	1991
Linear paraffins	60	1991
Tula		
Olefins ^d	50	1991
Linear paraffins	60	1991
Lazaro Cardenas		
Ammonia	445	1989
Camargo		
Ammonia	445	1990

a These plants will come on stream between 1988 and 1991. b by the planning stage. c Converted from an old propylene tetramer plant. d Feedstock for biodegradable detergents. Source: Pemex (Petróleos Mexicanos)

ton-per-year unit—which is scheduled for completion in 1988. In 1989, a 150,000-metric-ton acetaldehyde plant is expected to be on stream and, in 1990, Mexico's first linear low-density polyethylene unit, with a capacity of 80,000 metric tons per year, likely will be finished at Morelos.

Meanwhile, Pemex is eyeing a vinyl chloride plant at Pajaritos, where it already has 270,000 metric tons of capacity. The proposed new capacity will be between 200,000 and 300,000 metric tons per year, but the final decision on the plant will depend on future demand for polyvinyl chloride products. A lot depends, too, on whether the private sector will build a caustic-chlorine plant near Pajaritos large enough to support the proposed new vinyl chloride unit.

Pemex has modified its plans for a new petrochemical refinery. Originally, the petrochemical refinery was to be built at Lazaro Cardenas, and much of it was to be based on natural gas. Recent studies show that Mexico's natural gas supply won't be so high as Pemex originally thought. As a result, plans for the new petrochemical refinery have been changed.

First, the plant will be geared to oil-based feedstocks. And it will be built in two stages. The first stage will be an aromatics complex to help ease Mexico's aromatics shortage. And it will go up at Salina Cruz instead of Lazaro Cardenas.

The Salina Cruz aromatics complex will produce annually 275,000 metric tons of benzene, 120,000 metric tons of toluene, 200,000 metric tons of *p*-xylene, and 30,000 metric tons of *o*-xylene. In addition, 29,000 metric tons of heavy aromatics will be produced there.

Meanwhile, engineering studies already are under way for the second stage of Pemex's petrochemical refinery. This probably will be built at the original Lazaro Cardenas site and will focus on olefins. The complex will contain still another 500,000 metric-ton-per-year ethylene plant, a 350,000-metric-ton propylene plant, and units to produce ethylbenzene, alpha olefins, polypropylene, propylene oxide, and butadiene. A linear low-density polyeth-

ylene unit also had been planned, with a capacity of 240,000 metric tons. This unit, however, was switched over to Morelos and its size reduced to 80,000 metric tons.

Shorter term, Pemex will have on stream next year another 50,000-metric-ton acrylonitrile plant at San Martin Texmelucan. And at Ciudad Madero, the company is converting an old propylene tetramer unit to produce 20,000 metric tons of cumene. At the same site, Pemex also will build a 30,000-metric-ton plant to produce methyl *tert*-butyl ether.

By 1991, Pemex also plans to build a 50,000 metric-ton-per-year plant at Salamanca to produce olefin raw materials for biodegradable detergents and an identical unit at Tula. And 60,000-metric-ton linear paraffin units will go up at these same two sites.

Although Pemex already has almost 2.9 million metric tons a year of ammonia capacity on stream, it is planning for more. Its present in-

vestment program calls for completing two 445,000-metric-ton plants—one at Lazaro Cardenas by 1989 and another at Camargo by 1990. By 1993, if demand warrants it, Pemex may consider building still another 445,000-metric-ton ammonia plant.

If Pemex is able to get the funds it needs to fulfill its current petrochemical investment plans, and if it is able to complete the projects on schedule, the company will make a big dent in Mexico's petrochemical import bill. It also will be able to provide the secondary petrochemical industry with the raw materials it will need to become serious exporters.

In the private, secondary sector of the industry, the mood is hopeful. But nobody is taking anything for granted. They have watched similar pronouncements flow out of Pemex before. And they have watched Pemex petrochemical projects fall years behind schedule.

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Page 34

DECEMBER 8, 1986

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CHEMICAL & ENGINEERING

NEWS



AIDS THERAPY

No cure in sight, but drug, vaccine leads proliferate
Page 7

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News of the Week

■ **Unilever seeks to acquire Chesebrough-Pond's, as chemical merger activity heats up before tax reform law takes effect.** Page 4

■ **William Graham, new Presidential science adviser, outlines prevailing themes in the Office of Science & Technology Policy.** Page 4

■ **Low-cost, easy-to-use kit for drug screening is now available from Keystone Medical Corp.** Page 5

■ **Finnish chemicals producer Kemira buys Belgian nitrogen and fertilizer operations in attempt to boost its output, particularly in European Economic Community countries.** Page 5

■ **Allegedly falsified research data published in JACS is withdrawn by noted organic chemist Ronald Braslow.** Page 6

■ **In the Bhopal case, Indian court frees Union Carbide's assets, thus enabling Carbide to proceed with its reorganization and recapitalization plans.** Page 6

Cover: Crystal of azidothymidine, a promising anti-AIDS drug, photographed in polarized light, magnified 25 times. Copyright Will and Deni McIntyre

Letters 2

Concentrates

Business 17

Government 25

Science/Technology 28

The Departments

New Products 46

Newsclips 62

Business

Third-quarter earnings at major pharmaceutical firms continue the strong advances of second-quarter 1986. Page 22

Government

U.S. drug companies' problems in the world marketplace include lack of patent protection in many countries, political implications of World Health Organization's guidelines on pharmaceuticals. Page 26

Science

Use of fredericamycin A in cancer therapy may be closer: Its parent compound has been synthesized and there is evidence that free radical formation may be a key to its anticancer activity. Page 30

Technology

Silicone heat-transfer fluids are taking a larger share of the market because of their wide useful temperature range. Page 32

Meetings

1987 Pittsburgh Conference miniprogram includes symposium sessions, registration and other information. Page 34



News Focus

The quest for drugs to treat AIDS and a vaccine to prevent it is intensifying and taking many different directions. Page 7

Efforts Intensify To Develop Drugs, Vaccines that Combat AIDS

Dozens of potential treatments are in clinical and preclinical study, and a variety of strategies are being explored to protect healthy people from the virus that causes AIDS

Ron Dagani, C&EN Washington

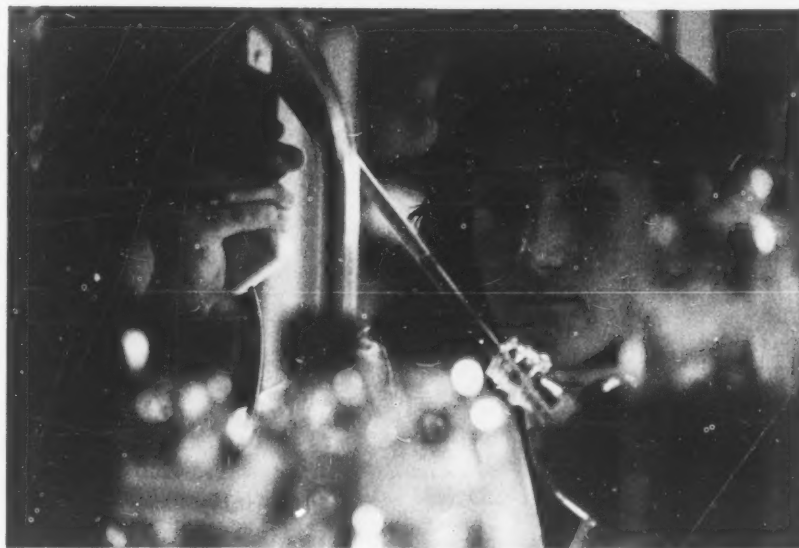
This is the second of a two-part series on the AIDS crisis. Last week C&EN published an article outlining the progress researchers have made in elucidating the nature, behavior, and biological effects of the AIDS virus (Dec. 1, page 7). This concluding article deals with efforts to develop drugs to treat AIDS and vaccines to prevent it.

Seven years ago few had ever heard of acquired immune deficiency syndrome, or AIDS. This puzzling affliction, then seen in only a small number of young, homosexual men, was something new and unnamed. Today, it's hard to find anyone in the U.S. who hasn't heard of AIDS, the disease that can debilitate and then kill its victim with horrific swiftness.

AIDS has come to be recognized as a public health emergency. More than 27,700 American men, women, and children have been stricken by it; the death toll is 16,000 and rising. The U.S. Public Health Service predicts that by the end of 1991 more than 179,000 persons will have succumbed to the disease.

So far, there is no cure—not even a satisfactory treatment—for AIDS. And a vaccine, if it's possible to develop one at all, won't be available for at least five years.

Nonetheless, the fear, despair, and helplessness surrounding the disease are just beginning to be counterbalanced by a measure of hope. At research centers and hospitals around the world, scientists and physicians are engaged in a frantic search for drugs and vaccines to stem the growing epidemic. One drug—



Scientist does antiviral research at Burroughs Wellcome Co., maker of AZT

azidothymidine (AZT)—has already shown some benefits in AIDS patients. And dozens of other potential treatments are in various stages of clinical and preclinical study. In addition, a variety of vaccine strategies are being explored to protect healthy people from the virus that causes AIDS. Many researchers seem optimistic that progress will be made, albeit slowly.

Medical researchers face a most formidable—and unique—enemy. AIDS is the first infectious disease in history that specifically targets the body's immune system. Once it has crippled that complex network of defenses, a host of other pathogens can invade the body and run wild, causing so-called opportunistic infections. Those infections are what make AIDS fatal. Thus, scientists have been handed an unprecedented triple challenge: Stop the AIDS virus, restore the dam-

A selection of experimental anti-AIDS drugs at a glance

AL 721. Lipid mixture composed of neutral glycerides, phosphatidylcholine, and phosphatidylethanolamine in 7:2:1 ratio. Interferes with HIV infectivity but not by inhibiting reverse transcriptase; possibly it disrupts the virus's membrane. No adverse effects observed during a six-week clinical trial.

Ampligen. Mismatched double-stranded RNA polynucleotide that induces the body to release interferon, thus stimulating antiviral activity. Reportedly does not have side effects of interferon injections. Currently undergoing preliminary clinical trials in AIDS patients.

Ansamycin (rifabutin, $C_{45}H_{29}N_4O_{11}$). Italian antibacterial drug, a member of the rifamycin group of antibiotics, which are characterized by a natural ansa structure (chromophoric naphthohydroquinone group spanned by a long aliphatic bridge). Drug has shown some efficacy in treating AIDS patients with an opportunistic in-

fection caused by the bacterium *Mycobacterium avium-intracellulare*.

Azidothymidine (AZT, 3'-azido-3'-deoxythymidine). First drug to show promise in prolonging lives of patients with AIDS or AIDS-related complex (ARC). Well absorbed orally and effectively penetrates central nervous system, but has relatively short half-life in the body and some toxicity, with anemia and headaches. ARC patients treated with AZT showed virtually no toxic effects.

Azimexon. Cyanaziridinyl immune modulator. Early trial showed improvements in symptoms and immune function in patients with ARC but not AIDS; only toxic effect was mild hemolysis (disintegration of red blood cells with release of hemoglobin), which disappeared when treatment ceased.

Cyclosporine (cyclosporin A). Cyclic oligopeptide with potent immunosuppres-

sive effects, used in cancer therapy. Inhibits T4 lymphocyte-dependent immune responses. Basis of controversial AIDS therapy in France; rationale is that HIV infects "activated" T4 cells, which are primed to defend that body, so drug that prevents activation of T4 cells may limit progression of disease. The French claim encouraging results with it.

Foscarnet (trisodium phosphonoformate). Swedish drug that has been used to treat CMV infection in immunocompromised patients, also to treat herpes. Inhibits HIV reverse transcriptase activity in vitro at levels pharmacologically acceptable in vivo. Formulation problems and serious side effects have been encountered. No results yet reported in HIV-infected patients.

HPA-23 (ammonium 21-tungsto-9-antimoniate, $[(NH_4)_{18}(NaW_{21}Sb_9O_{86})_{17}]$). Used to treat actor Rock Hudson in Paris. Inhibits reverse transcriptase in

aged immune system, and treat the opportunistic infection.

No one believes a single "magic bullet" will do it all. Immunologist Matthew F. Heil thinks therapy for AIDS patients likely will consist of "a successive series of stopgap measures"—drugs to stop the virus from reproducing, drugs to boost the immune response, and drugs to treat the opportunistic infections. Step by step, scientists will slowly learn how to extend the life span of AIDS patients, says Heil, a consultant to the biotechnology industry. "It's not going to happen all at once," he cautions.

An important first step, though, has already been taken. In a recent study, AIDS patients given the antiviral drug AZT resisted opportunistic infections better and remained alive in greater numbers than patients given a placebo (C&EN, Sept. 29, page 6). The survival disparity between the two groups of patients became so dramatic that the trial was halted prematurely so the placebo group could be switched to AZT therapy. Most of those patients are still receiving the drug, and scientists are anxiously waiting to see how long it will keep them alive.

In the meantime, new clinical trials of AZT have begun, including one that involves children with AIDS. And Burroughs Wellcome Co., the North Carolina firm that manufactures the drug, is now offering it to thousands of additional AIDS sufferers. Early in 1987, the Food & Drug Administration is expected to give the company the nod to market the drug.

Although AZT has given certain AIDS patients new hope, it probably won't be the ultimate weapon against

the disease. The drug has a number of drawbacks, the chief one being that it suppresses production of the body's bone marrow cells. Such a side effect could not be tolerated for the long period of time—perhaps a lifetime—that the patient might have to take the drug.

The international search for therapeutic agents against AIDS is only beginning, and as a result, it appears to be in some disarray. Basically, researchers are trying almost anything that looks like it might be able to stop human immunodeficiency virus (HIV), the retrovirus that causes AIDS, in its tracks. Some of the candidate drugs being tested, such as ansamycin and ribavirin, are established drugs for other ailments. Other candidates, such as AZT and its chemical cousins, have emerged from ambitious drug-screening programs. The National Cancer Institute, for instance, has a repository of more than 500,000 medicinal compounds that it is screening for activity against HIV.

Scientists also are trying to design new anti-AIDS drugs from scratch. The National Institutes of Health is making a major effort in this direction. Leading the initiative are the National Institute of Allergy & Infectious Diseases (NIAID) and NCI, which together are funneling \$11.5 million this fiscal year to researchers through five cooperative drug-discovery groups.

Some of the new drug-discovery initiatives are aimed at blocking various stages in the life cycle of the AIDS virus. To reproduce, the virus must bind to a host cell, enter it, and then shed its viral coat, freeing its RNA genome. Using its own reverse transcriptase, the virus makes a double-stranded DNA copy of its genome. The copy is integrated into the host cell's chromo-

several retroviruses in vitro, but mechanism of antiviral action against HIV is unknown. Drug has shown some tendency to check the growth of HIV, but no therapeutic benefit has been documented in AIDS patients.

Imreg-1. Proprietary immune modulator derived from white blood cells. Reportedly can enhance production of other biological response modifiers such as interleukin-2 and γ -interferon, which are critical to normal functioning of immune system.

Inosine pranobex (isoprinosine, inosiplex). *p*-Acetamidobenzoic acid salt of dimethylaminoisopropanol:inosinate complex (3:1 molar ratio). Chemically synthesized antiviral and immune modulator originally developed to enhance memory in elderly. In one study, found to improve immune function in ARC patients.

α -Interferon. Glycoprotein produced by

cells in response to virus infection; helps amplify or regulate immune responses. Checks the growth of HIV in vitro. Has induced tumor regression in some AIDS-related Kaposi's sarcoma cases. Not known whether α -interferon has anti-HIV activity in vivo.

Interleukin-2 (IL-2). Protein made by white blood cells that mediates production of interferon. Inability to produce IL-2 may predispose AIDS patients to opportunistic infections. Preliminary results of therapy with recombinant IL-2 not encouraging, but trials continue.

D-Penicillamine (3-mercapto-D-valine). Used to treat rheumatoid arthritis and Wilson's disease, a rare copper-storage disease. Inhibits HIV reproduction in humans. In trials at George Washington University Medical Center, it suppressed the virus but also temporarily depressed T cell levels in 13 AIDS patients with perpetually swollen glands.

Ribavirin (1- β -D-ribofuranosyl-1,2,4-triazole-3-carboxamide). Synthetic nucleoside used to treat a viral respiratory infection in children. In early clinical trials, it inhibited viral replication and improved immune function in AIDS patients. Longer (24-week) trial in 373 ARC patients was completed last month; at 12 weeks, ribavirin's safety profile was judged to be acceptable, and the drug was found to be well tolerated. Final results will be available soon.

Suramin ($C_{51}H_{34}N_6Na_6O_{23}S_6$). Antiparasitic agent. Potent inhibitor of HIV reverse transcriptase, but also significantly inhibits desirable biological functions. In AIDS patients, it has produced little or no evidence of clinical improvement or immunologic recovery. Has serious side effects, inability to penetrate central nervous system. Not considered appropriate for single-agent use in AIDS. No longer being actively pursued.

some and transcribed into RNA. Following a complicated series of events, the new RNA is encapsulated inside a newly constructed virus shell. The virus particle thus created buds from the host cell and can proceed to infect a new cell.

These processes are controlled by HIV's genes, of which there are at least seven. Each of the genes, and the protein products whose production they control, could serve as a specific target for new therapeutic strategies, says Samuel Broder, who directs clinical research at NCI. Broder's research group, for instance, is exploring the possibility of inhibiting the *tat*-III gene or the *tr*s (also known as *art*) gene. These two genes make regulatory—as opposed to structural—proteins, and if they could be “knocked out,” the virus might not be able to reproduce.

AZT and most of the other compounds presently being touted as potential weapons against AIDS were picked out initially because they were shown to inhibit replication of the virus in vitro. Many of these compounds are thought to do this by interfering with reverse transcriptase, a key viral enzyme in the replication process. This enzyme builds a DNA copy of the virus's RNA genome using thymidine triphosphate and other nucleotide building blocks found in the host cell. AZT can bollix this process, presumably, because reverse transcriptase mistakes AZT triphosphate for thymidine triphosphate and incorporates the azido derivative in the growing DNA chain. Then, when the enzyme attempts to append the next nucleotide, it is stymied because the necessary 3'-hydroxy group on the “ersatz thymidine” (AZT) is missing.

The chain is thus terminated, and so is the virus's replication.

Researchers have synthesized other “false building blocks”—some of them structurally very similar to AZT—that they believe may be more potent and less toxic than AZT. For example, NCI has just begun testing 2',3'-dideoxycytidine in patients with AIDS or a milder form of the disease known as AIDS-related complex (ARC). Dideoxycytidine is “the most potent drug we've found so far,” Broder says. Another nucleoside analog, 2',3'-dideoxyadenosine, also is being given high priority as a potential anti-AIDS agent by government scientists.

Ribavirin, a triazole nucleoside that has been pitted against more kinds of viruses than any other antiviral agent, also shows promising activity in AIDS patients. In a short-term clinical trial, ribavirin inhibited HIV replication and enhanced the immune system. More-extensive clinical trials to test the drug's safety and efficacy have now been completed and results are expected soon.

At the University of Georgia, chemist Chung K. Chu has synthesized some 60 nucleoside analogs related to AZT as part of a drug discovery effort led by Raymond F. Schinazi, a viral pharmacologist at the Veterans Administration Medical Center and Emory University, both in Atlanta. One of their most promising candidates is 3'-azido-2',3'-dideoxy-5-ethyluridine, code-named CS-85. Structurally, it differs from AZT only in that the pyrimidine ring has an ethyl group instead of a methyl at the 5-position. CS-85 inhibits viral replication and, when tested in human bone

marrow cells, was found to be much less toxic than AZT. CS-85 hasn't yet been tested in humans.

One limitation of CS-85 is that it doesn't prevent HIV-infected cells from binding to healthy cells. This fusion process depletes the immune system of important cells called T4 lymphocytes. Schinazi has found that several members of a class of inorganic compounds called heteropolytungstates can prevent fusion in cultured cells that are already infected. One example is silicotungstic acid, $H_4[SiO_4 \cdot (W_3O_9)_4]$, an industrial chemical that Emory University chemist Craig L. Hill made for Schinazi in highly purified form. This and other heteropolytungstates are "essentially nontoxic" in cell culture, Schinazi says, and he hopes to begin examining their effects in monkeys soon. They may turn out to be an improvement over HPA-23, an antimoniotungstate that has produced mixed results in AIDS patients.

Other potential anti-HIV drugs now being studied operate via still other mechanisms, the majority of which are not completely understood. For instance, a

mayonnaiselike mixture of lipids called AL 721 appears to kill the AIDS virus by disrupting its protein membrane. And recombinant α -interferon seems to make cells resistant to infection by HIV.

But whatever its mechanism of action, an effective antiviral must be able to penetrate the blood-brain barrier. This capability is particularly important for treating patients with advanced cases of AIDS, because HIV is known to seek sanctuary in the brain of such patients.

Besides antiviral agents, scientists also are evaluating a variety of immune modulators that might be able to reinvigorate the AIDS patient's weakened defenses against infections. Some immune modulators, like ampliten and interleukin-2, mediate the body's own production of interferons (glycoproteins important in the immune response). Others, like isoprinosine and α -interferon, appear to have both immunostimulatory and antiviral activity, at least in vitro.

Several immune modulators have shown some promise in treating specific opportunistic infections. In one early trial of α -interferon, for example, a number of AIDS patients with Kaposi's sarcoma (a cancer that originates in blood-vessel walls) achieved complete remission, even though the researchers saw no signs of immune enhancement.

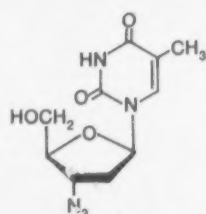
Researchers also have been trying to restore the immune system using more direct means. In the most successful approach so far, an AIDS patient who received bone-marrow transplants from his identical twin brother 15 months ago continues to improve, according to NIAID director Anthony S. Fauci. But whether this strategy can correct the underlying immune defect permanently is unknown.

Because the vast majority of persons infected with HIV presently show no clinical signs of AIDS-related infections or malignancies, there obviously is a need for antiviral drugs that will prevent these individuals from developing ARC or full-blown AIDS. But the testing of experimental drugs in those infected yet healthy persons could pose major practical and ethical problems because the drugs could be potentially dangerous. Furthermore, evaluating whether a candidate drug has protective effects would require volunteers to be monitored for years. That's because HIV has the cunning ability to remain latent in its host for long periods of time before it starts its devastating rampage through the immune system. Scientists don't understand what causes the virus to arise from its dormancy. Until they do, they have little chance of developing chemotherapy to eliminate the virus.

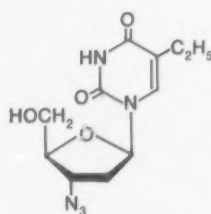
If a drug is developed that limits—but does not eliminate—expression of the virus, lifelong therapy may be necessary to protect infected persons. And "if lifelong therapy is required, the already difficult challenge of devising drugs of acceptable toxicity will prove even more severe," warns a book-length report on AIDS issued last month by the Institute of Medicine and the National Academy of Sciences (C&EN, Nov. 3, page 4).

Because of HIV's ability to hibernate in the body, it may not be possible to root it out. Antiviral drugs

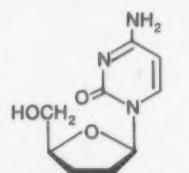
Some experimental anti-AIDS drugs have relatively simple structures



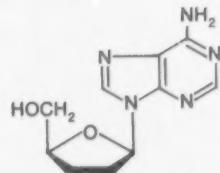
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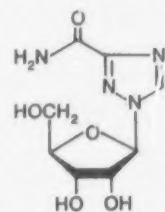
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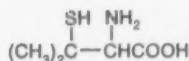
2',3'-Dideoxycytidine



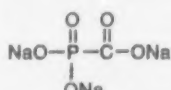
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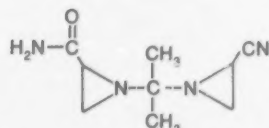
Ribavirin



D-Penicillamine

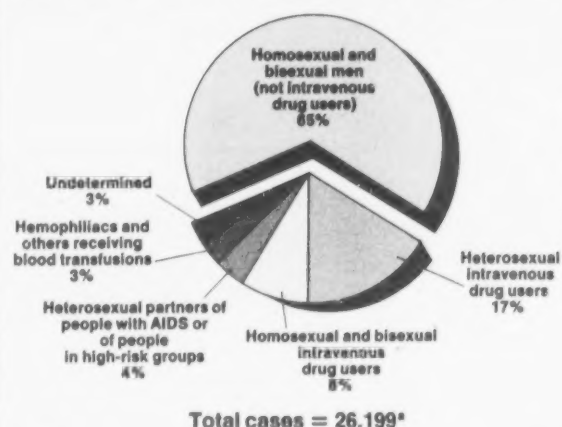


Foscarnet



Azimexon

Most AIDS cases are sexually transmitted



* Adult and adolescent cases in U.S., reported between 1981 and Oct. 20, 1986.
Source: Centers for Disease Control

might be able to keep the virus in check, but they probably won't be able to cure the disease.

Therefore, the most promising way to deal with the deadly threat of HIV is to prevent infection in the first place. Scientists only recently have begun to search for a vaccine against AIDS. And if their track record for producing vaccines against other animal retroviruses is any indication, their current quest will be slow and fraught with difficulties. In fact, some researchers even question whether an effective AIDS vaccine is possible.

A vaccine against AIDS might be derived from a harmless variant of the disease-causing agent, HIV. Such a variant would contain an antigen, or protein that triggers the immune system to produce neutralizing antibodies—specialized proteins that recognize and attack HIV particles if they enter the body later.

But it's not that simple. HIV is an immensely formidable foe because it uses "every biological trick in the book," says biotechnology consultant Heil. For example, according to a recent report on AIDS from Johns Hopkins University, "although some persons naturally produce antibodies to HIV that are weakly protective, these antibodies generally do not destroy the virus." However, the report goes on to say, "This does not necessarily mean that vaccine-induced antibodies will not destroy the virus [because] they may be quite different from those induced by the natural virus."

A related problem is the disquieting possibility that the AIDS virus can sneak into the body stowed away inside cells found in blood and semen, Emory's Schinazi says. Such infected cells then could fuse with healthy T lymphocytes, undermining the immune response and creating virus factories in the same blow. No one can say whether a vaccine would be effective against this cell-to-cell route of transmission.

A further difficulty confounding vaccine developers is the virus's genetic variability. Numerous strains of HIV are known, and the protein structure of each of

these variants is significantly different, especially in the virus's outer coat (envelope), which is the part usually recognized and attacked by antibodies. New HIV strains are continually appearing because the virus mutates rapidly. Therefore, a vaccine derived from the envelope of one strain might not protect against other strains because the antibodies it induces might not recognize them.

In trying to block infection by the AIDS virus, researchers are exploring many avenues. One of these involves identifying the viral proteins or protein fragments that will elicit a protective immune response. This might be accomplished, for example, by isolating protein from HIV or chemically synthesizing peptide fragments of an HIV protein. Because of HIV's genetic variability, researchers are examining different strains of the virus, hoping to identify the envelope proteins that remain constant. These antigenic proteins possibly could serve as subunits for a vaccine that would be effective against a variety of strains.

It might also be possible to develop a vaccine that would induce antibodies to attack the inner-core (*gag*) proteins of HIV, which apparently vary less than the envelope proteins. Researchers Prem S. Sarin of NCI, Allan L. Goldstein of George Washington University school of medicine, and their coworkers recently found that antibodies to a synthetic version of a natural human thymic hormone called thymosin α_1 attack the *gag* protein, neutralizing HIV in vitro. This occurs because the *gag* protein resembles thymosin in certain amino acid sequences. Thus, a vaccine based on thymosin, the *gag* protein, or synthetic peptides resembling their homologous region might immunize people successfully.

Antigenic viral proteins also can be produced using genetic engineering techniques. Recently, for example, Laurence A. Lasky, Phillip W. Berman, and their coworkers at Genentech in South San Francisco induced a mammalian cell line to make an HIV envelope glycoprotein that elicited antibodies in rabbits and guinea pigs. Some of these antibodies were shown to inactivate the AIDS virus in vitro by Jerome E. Groopman's group at New England Deaconess Hospital in Boston. Genentech researchers are believed to be testing the glycoprotein in chimpanzees to see if the animals produce neutralizing antibodies. If they do, they will be challenged with the AIDS virus to see if they are protected from infection.

Another recombinant approach to a vaccine was reported recently by two independent research groups. They spliced the envelope gene *env* of HIV into the vaccinia virus, which forms the basis of the smallpox vaccine. One group, led by Shiu-Lok Hu of Oncogen in Seattle, showed that macaque monkeys injected with this recombinant virus not only produced antibodies to HIV envelope proteins but triggered T lymphocytes to mount a cellular immune response (C&EN, Sept. 29, page 6). Hu's team is studying the vaccine in chimpanzees to see whether it protects against the virus.

The other group, consisting of Bernard Moss of NIAID and his colleagues there and at NCI, treated

NCI photo



NCI's Broder (left) and Emory University's Schinazi are studying antiviral activity of nucleoside analogs and other potential drugs



C&EN staff photo

monkeys with a similarly altered vaccinia virus, removed their cells, and exposed these to live AIDS virus in vitro. The cells did not become infected.

Although these results are encouraging, vaccinia virus has at least one major drawback: It could cause serious infection if given to a person whose immune system is already compromised.

Scientists also are considering the possibility that a naturally occurring, nonpathogenic relative of HIV might serve as the basis of an AIDS vaccine. Earlier this year, an international team of researchers led by virologist Myron E. Essex of the Harvard School of Public Health reported finding a new virus in healthy female prostitutes in Senegal. The new virus is genetically similar to HIV and is called HTLV-IV, that is, the fourth member of the human T-cell lymphotropic virus family, of which HIV also is a member.

HTLV-IV, which has infected people in western Africa for years, induces neutralizing antibodies to AIDS. So far, though, it does not seem to have caused the disease itself. Essex's group is examining the possibility that persons infected with HTLV-IV are protected from subsequent infection with HIV. "There may be a vaccine lead in this direction," Heil comments, "but you would have to be dead certain that HTLV-IV doesn't cause AIDS."

Essex's approach may have some allure because live-virus vaccines have tended to elicit a better immune response than vaccines based on killed virus, viral fragments, or other proteins.

But in the case of AIDS, most researchers are wary of using a live virus as a vaccine, according to molecular biologist Joseph G. Sodroski of Harvard's Dana-Farber Cancer Institute in Boston. "No one's going to inject a live retrovirus into healthy people," he says. "Even if it couldn't cause AIDS, there would be no way to guarantee that it wouldn't cause malignancy in 10 or 15 years."

Similarly, the use of killed HIV as an AIDS vaccine is suspect because of fears the virus might revitalize itself.

In their quest for an AIDS vaccine, scientists are having to contend with several research-related obstacles. The most basic one, of course, is their limited understanding of the immune response to HIV infection. Another is the scarcity of chimpanzees, which are needed to test the safety and efficacy of experimental HIV vaccines before clinical trials. Chimpanzees have been declared an endangered species; only about 1400 are now available for all biomedical research, according to NAS. As important as chimps are, though, they are deficient as an animal model for studying AIDS infection and disease, and that, too, has slowed vaccine development, notes NCI

researcher Robert C. Gallo.

Assuming a vaccine does emerge from animal tests, the human testing will pose practical and ethical problems. For example, testing an HIV vaccine in uninfected volunteers would seem to require that some of them engage in high-risk activities so as to expose themselves to the deadly virus. In addition, a vaccine's side effects might discourage healthy, high-risk individuals from volunteering for trials.

Economic and legal considerations also are retarding vaccine research. Large pharmaceutical firms are reluctant to commit to vaccine development because such programs tend to be extremely expensive and traditionally have not provided a high return on investment capital. Pharmaceutical companies also are concerned that they would be sued for any vaccine-related injuries.

In light of these realities and uncertainties, no one expects an AIDS vaccine to become available before the early 1990s.

Nevertheless, Harvard's Essex predicts that vaccine development will see "dramatic progress" within the next two to three years. "Certainly within a year we'll have a much better idea of the feasibility for success," he says.

For now, though, the best preventative is education, according to U.S. Surgeon General C. Everett Koop and other public health officials. Their most basic message is that every adult and adolescent must be made aware that they can virtually eliminate their risk of infection by following two guidelines:

- Use a condom during sexual intercourse—either anal or vaginal—with someone who might be infected.
- Avoid illegal intravenous drugs, or at the very least, don't share needles and syringes.

That message, public health experts say, must be spread to all corners of society if society is to survive the specter of AIDS. □

Pharmaceutical Earnings Remain High

Earnings at major U.S. pharmaceutical companies continued their strong advances in the third quarter, but profit margins fell on average, as sales gains outpaced those for profits.

For 14 major drug-producing firms, after-tax earnings, excluding extraordinary and nonrecurring items, rose an average of 14% from last year's third quarter to a total of \$1.42 billion. Sales for the group increased 21% to \$11.5 billion. The group's average profit margin (after-tax earnings as a percentage of sales) dropped to 12.3% from 13.1% in the third quarter of 1985.

As in the second quarter, companies credited increased foreign sales brought about by the weaker dollar for much of the improvement. For instance, at Schering-Plough, Robert P. Luciano, chairman and chief executive officer, says the company's third-quarter results reflect an "exceptional" 32% increase in worldwide pharmaceutical sales. Luciano says the international pharmaceutical business continued to show a strong sales increase, both as reported in dollars and as measured in local currencies. Schering-Plough

had an earnings increase of 42% to \$62.3 million for the quarter on a sales rise of 19% to \$601 million.

For Upjohn, whose sales increased 18% to \$561 million and earnings rose 33% to \$60.6 million, foreign sales increased 20% to \$197 million and amounted to 35% of the company's consolidated sales.

Edmund T. Pratt Jr., chairman and chief executive officer of Pfizer, says the weaker dollar had a favorable impact on his company's reported results. "The effect of currency translation improved worldwide sales growth from 8% to 15% in the third quarter and from 6% to 12% for the first nine months of 1986," he says. Pfizer's earnings in the third quarter rose 14% to \$177 million on that 15% sales increase to \$1.16 billion.

Sterling Drug, which had a 14% rise in earnings to \$51.3 million and a 20% increase in sales to \$558 million, says the substantial sales gain for Sterling International, which encompasses all of the company's businesses abroad, was led by significant increases in Europe and Canada. But the favorable effect of the weakening of the dollar against major European currencies was large-

ly offset by unfavorable currency effects in other parts of the world.

Productivity also played its share in improving earnings for the quarter. At Merck, whose earnings rose 27% to \$173 million on a sales gain of 23% to \$1.05 billion, chairman and chief executive officer P. Roy Vagelos says, "Income gains and improved earnings margins resulted from a better product mix and the continuation of cost controls and productivity improvements." He also credits the weaker dollar.

One company on the list—Baxter Travenol—recorded a 167% sales growth in the quarter to \$1.38 billion. This was due to the company's acquisition of American Hospital Products in late 1985. The firm's earnings growth was a more normal 20% to \$49 million.

For the first nine months of this year, the 14 companies had an average earnings growth of 14% to a combined \$4.06 billion on a 19% sales increase to \$33.6 billion. Profitability averaged 12.1% in the first three quarters this year compared with 12.7% in the comparable period last year.

William Storck, New York

Third-quarter earnings up sharply at many pharmaceutical companies

	THIRD-QUARTER 1986						NINE-MONTHS 1986					
	Sales (\$ millions)	Earnings ^a	Change from 1985		Profit margin ^b		Sales (\$ millions)	Earnings ^a	Change from 1985		Profit margin ^b	
			1985	1986	1985	1986			1985	1986	1985	1986
American Home Products	\$1271.0	\$201.3	5%	-2%	15.8%	17.0%	\$3733.7	\$579.5	6%	9%	15.5%	15.1%
Baxter Travenol	1382.0	49.0	167	20	3.5	7.9	4108.0	122.0	171	6	3.0	7.6
Becton Dickinson	389.6	31.5	23	9	8.1	9.1	1311.6	111.9	15	27	8.5	7.7
Bristol-Myers	1264.6	173.9	8	20	13.8	12.3	3630.2	437.8	9	12	12.1	11.7
Lilly	883.4	135.6	12	11	15.3	15.5	2751.0	433.9	12	10	15.8	16.0
Merck	1053.7	173.0	23	27	16.4	15.9	2979.8	503.9	15	24	16.9	15.7
Pfizer	1163.1	176.6	15	14	15.2	15.4	3313.1	501.6	12	14	15.1	14.8
A. H. Robins	215.0	25.0	14	40	11.6	9.4	579.1	55.6	11	25	9.6	8.6
Schering-Plough	600.6	62.3	19	42	10.4	8.6	1798.6	205.9	16	31	11.4	10.2
SmithKline Beckman	956.4	134.0	17	2	14.0	16.0	2702.1	402.6	14	5	14.9	16.3
Squibb	462.8	78.5	31	26	17.0	17.7	1277.8	192.4	27	19	15.1	16.0
Sterling Drug	557.8	51.3	20	14	9.2	9.7	1466.8	123.2	14	12	8.4	8.6
Upjohn	561.2	60.6	18	33	10.8	9.6	1692.8	188.3	13	23	11.1	10.2
Warner-Lambert	782.2	67.3	-6	10	8.6	7.3	2290.3	205.0	-6	9	9.0	7.7

^a Earnings from continuing operations excluding significant nonrecurring and extraordinary items. ^b After-tax earnings as a percentage of sales.

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CHEMICAL & ENGINEERING

NEWS



WORLD CHEMICAL OUTLOOK

PAGE 20

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News of the Week

■ **Synthetic versions of two different amino acid segments might lead to the development of a vaccine for AIDS.** Page 4

■ **ACS Board of Directors elects Ernest L. Ellet chairman for 1987; committee heads named.** Page 5

■ **A worldwide protocol to protect the stratospheric ozone layer is gradually evolving through the UN Environment Program.** Page 6

■ **Monoclonal antibodies can be used to catalyze hydrolysis of esters and carbonates with great specificity.** Page 6

Business

The liability battle over Bhopal, between the government of India and Union Carbide, is entering a new phase, that of gathering evidence to be presented in a trial that may last as long as 10 years. Page 9

International Business

Finland's chemical industry is striving to expand internationally both to compensate for a small domestic market and to counteract the oil-price squeeze that is hurting its large oil-refining products sector. Page 13

Government

EPA seeks to delay setting effluent limitations, pretreatment standards for organic chemicals, plastics, and synthetic fiber plants to allow comments from interested parties. Page 16

Science

Center for Photochemical Sciences at Bowling Green State University provides the non-Ph.D.-granting school with a research specialty to train students and to serve as a photochemical data clearinghouse. Page 18

ACS News

Chemical Abstracts Service will add 16 new titles to its *CA Selects* series, two to its *CAS Biotech Updates*. Page 47

Letters	2
Concentrates	
Business	7
Government	15
Science/Technology	17
The Department	
Newsclips	60



Special Report

Worldwide the chemical industry in 1986 was basically sound. Slow growth in some areas was counterbalanced by plunge in petrochemical feedstock prices, trimming of industry operations to make them cost efficient. Page 21

Oil-Price Squeeze Slows Finland's International Expansion Efforts

Increase in chemical exports and acquisitions in other nations hurt by fall in value of oil-refining products and of oil, gas imports from U.S.S.R.

Patricia L. Layman, C&EN London

For the Finnish chemical industry, the bywords over the past several years have been "internationalization" and "specialization." There is nothing novel about that; the chemical industry worldwide has been working to move away from commodity chemicals to specialties. And very few major chemical producers are not multinational.

But for Finland, the problems have been particularly compelling. In a country with a small population and small domestic market, growth has been predicated on international expansion, both in exports and, more recently, in acquisitions. This year, however, the international drive has been caught in the oil-price squeeze that is affecting all Finnish industry, and the key challenge for the chemical industry is to minimize that squeeze.

Key to the oil-price squeeze is the long-standing payment-in-trade agreement with the Soviet Union. Finland buys a substantial portion of its oil and natural gas from the U.S.S.R. and in return, exports an equal value of goods and services to the Soviets. With the fall in crude oil prices, however, the value of the oil and natural gas brought into Finland has fallen, thereby directly reducing the amount of goods that can be sent back across the Gulf of Finland. Because of the oil price change, any such trade agreements will have to be renegotiated.

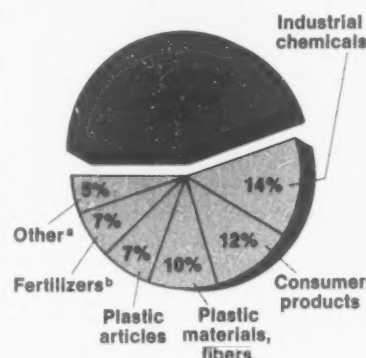
And in a double whammy, the oil-price decline also has hit the value of oil-refining products, by far the largest single category of the country's chemical exports. Similarly, the fall in the value of the U.S. dollar has had a major impact on the Finnish economy, making exports relatively more costly—a problem Finland faces with all its European neighbors. Finland's trade surplus at the end of the first three quarters of this year was \$355 million, \$226 million less than in the same period of 1985. Exports fell 6% and imports 4% from the previous year's level.

The gross value of Finnish chemical production in 1985 was \$5.63 billion, up 6% over 1984. The increase was made up of a 5% rise for industrial chemicals and oil-refining products, and a more than 9% rise for other chemical products—consumer items such as paints and pharmaceuticals. During the first three quarters of 1986, a slowdown occurred, although less in the chemical industry than in industry as a whole. Production of commodity chemicals increased 1.9%, and output of other chemical products rose 3.8% over the same period of 1985.

Moreover, that trend is expected to continue into the first half of 1987, according to Pertti Lehtiö, director for economics and statistics at the Chemical Industry Federation (CIF) of Finland, in Helsinki.

The increases in chemical production in Finland in 1986 came from improved domestic demand and in larger exports to western markets. Lehtiö cites a cut in exports to the Soviet Union as the main reason why chemical exports did not reach quite the same level as they were during the first three quarters of 1985. "Our other export markets are to Western Europe, and as the econ-

Oil refining dominates Finnish chemical industry



Total value = \$5.63 billion

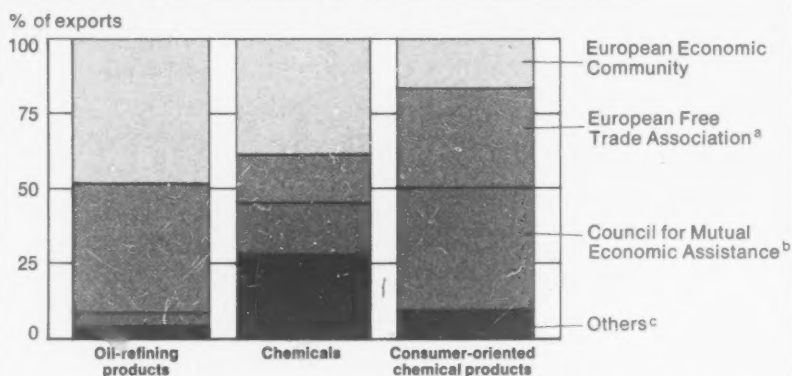
^a Rubber articles and petroleum products.
^b Includes agricultural chemicals.

omy there goes up, our exports will. But not so quickly as we would have wanted," he adds.

Fortunately for the Finnish chemical industry, its exports to the U.S.S.R. and other countries of the Council for Mutual Economic Assistance (CMEA) group, as the Eastern bloc countries prefer to call themselves, account for only about 20% of the total. Nonetheless, that is a significant chunk of business for the industry to see trimmed by changes in import/export agreements between Finland and the CMEA bloc, which are now being renegotiated.

So that puts even more pressure on the Finnish chemical industry to build internationally by exports and, increasingly, by acquisitions. CIF's managing director Raili Nuortila charts the expanded rate of acquisitions by the Finnish chemical industry since the beginning of the decade: Foreign sales of Finnish chemical companies have increased roughly 17-fold since 1981.

Chemical sectors show different export patterns



^a Non-EEC Western European countries. ^b Comecon countries. ^c Non-European countries.

And, she predicts, "I wouldn't be surprised if this acquisition program continued for some time. It is all company by company, not a countrywide strategy, but these companies have come to the same conclusion at the same time, based on the criteria of limited domestic markets and worldwide possibilities."

In about 1980, Finnish chemical companies started seriously considering a plan for boosting international business. Most companies started by targeting Scandinavian markets or making Scandinavian acquisitions. For example, the chemicals unit of Neste, the state-owned oil refiner and the largest chemical company, acquired 100% of its joint-venture raw materials company Pekema, in Sweden, about then. "We realized Finland would be too small for us," says Jukka Viinanen, senior vice president for polyolefins.

But that, and subsequent acquisitions in the Nordic area, finally brought the company to the point at which there was nothing more it could do in Scandinavia. Nothing it could do to expand in Norway, for example. "What we could do, we had already done. Therefore we decided to move into Europe," says Viinanen. And move in, Neste has done. Its latest move came in October when Neste agreed to buy the polypropylene plant and related businesses at Beringen, Belgium, from Himont Belgium. The capacity of the Beringen plant is 120,000 metric tons per year. At the same time, Neste announced it would build a new polypropylene plant

with an equal capacity at its Porvoo, Finland, plant site. The combined total will make Neste the sixth largest polypropylene producer in Europe.

Neste is already tied, with Dow, for third-largest producer of polyethylene in Europe, with total capacity of 620,000 metric tons per year. It is debottlenecking its phenol unit, to raise capacity to 75,000 metric tons per year, and it is switching its cumene process to the Monsanto process, doubling capacity to 140,000 metric tons in the existing plant.

"The players are getting bigger and stronger, and there will be fewer of them," Viinanen says. Neste, he adds, "is joining the top league," particularly in polyethylene, by competing throughout Europe.

Chemicals producer Kemira was using a similar strategy when it acquired American Cyanamid's titanium dioxide works in Savannah, Ga., in 1985. That deal made Kemira the fifth largest titanium dioxide producer in the world, with 80,000 metric tons of capacity in Finland, at Pori, and 88,000 metric tons in Savannah. It also gave the company important access to North American markets; Kemira already exports about 85% of its Pori-produced titanium dioxide.

But then, why should Finnish chemical companies not go international, asks Henry Tuderman, director of Nokia Chemicals, in Aetsä, a unit of pulp and paper producer Nokia Corp. "We are forced to compete on home ground with big international companies so why should

we not go anywhere else in the world?"

As Tuderman sees it, Finnish chemical companies have few alternatives to moving into the international marketing scene. For example, one of the major markets for chemicals in Finland—pulp and paper—is drifting away to other countries, he points out. The demand for chemicals is changing because of more recycled paper, harder pulps and stocks, and tightening environmental controls. Companies have to provide the products customers want, and the only way really to know what those product demands are is to be in the markets where the customers are, he suggests.

But how do companies enter those international markets successfully? For a relatively small country such as Finland, where companies might have trouble gathering sufficient resources to exploit international distribution or marketing, "strategic alliances" might fit the bill, suggests James R. Hickey, managing director of consultants Strategic Analysis Europe, in Brussels.

He cites as examples two new ventures involving Finnish firms working to move technology into the world market. In one, pharmaceuticals producer Orion Corp. of Espoo is working with Du Pont to commercialize Orion's patented technology in nucleic acid sandwich hybridization. Du Pont will use its know-how to market and improve the technology throughout the world.

Similarly, Nokia Chemicals has an agreement with Canadian engineering firm Chemetics International Co., in the Toronto suburb of North York, to build plants using Nokia's cell technology for sodium chlorate production. The deal brings the Finnish technology to the world marketplace with much more ease than might have been otherwise.

"Finland more than most other countries must look global, given the size of the domestic or Scandinavian market," Hickey argues. Business alliances of this nature will help the country's chemical industry penetrate foreign markets more rapidly. He predicts that the number of such ventures will rise, as Finnish firms continue to implement their internationalization strategy. □

WORLD CHEMICAL OUTLOOK

The world's chemical industry is ending 1986 in basically sound condition. Although demand is growing at a snail's pace for many chemical products, at least it generally is holding up. Agricultural chemicals, though, are a notable exception as crop surpluses crimp demand while manufacturing capacity continues to expand worldwide.

Offsetting the slow growth to a considerable degree, however, is the sharp drop in petrochemical feedstock prices during the past year or so. Even more beneficial have been the major efforts to restructure chemical operations in recent years. Marginal businesses have been shut down or sold off and manufacturing operations generally streamlined. The resulting reduction and consolidation of existing plant capacity have resulted in an international industry that is basically leaner and more cost efficient, and hence better structured to cope with the challenges that accompany increasing maturity.

That chemicals are still viewed as a key to economic growth is evident in the ambitious expansion plans of such disparate nations as the Soviet Union and its East European satellites; Mexico; and Saudi Arabia. That international competition remains fierce is clear from the marketing problems burdening chemical producers in Japan and Canada, not to mention the U.S. and Western Europe.

Slow growth notwithstanding, though, the economic foundations of the chemical industry seem firmer now than at any time in the recent past.

UNITED STATES	22
---------------	----

FOREIGN TRADE	27
---------------	----

WESTERN EUROPE	35
----------------	----

JAPAN	39
-------	----

CANADA	42
--------	----

U.S.S.R./EASTERN EUROPE	44
-------------------------	----

MEXICO	46
--------	----



UNITED STATES

Chemical output probably will continue to expand slowly, but profitability will be much improved for a restructured industry

David M. Klefer, C&EN Washington

The U.S. economy, as it enters its fifth year of expansion, clearly is creaking. Gross national product will rise a rather anemic 2 to 3% this year, close to the rate of growth chalked up in 1985. Industrial production, overall, will be up only about 1% for the year as a whole and is ending the year at about the same level at which it began.

The chemical industry is doing a bit better than that—but not by much. Output of industrial chemicals, for the year as a whole, will average about 4 to 5% higher than in 1985. But production now is less than 3% above what it was as the year began. Meanwhile, selling prices for industrial chemicals are down about 5% from year-ago levels. As a result, the industry's sales volume this year will be only marginally higher than last year.

In past years, such a business climate of slow demand growth and weak prices frequently led to depressed earnings. This year, however, is different. Profits have rebounded smartly for makers of industrial chemicals. For the year as a whole, in fact, operating income may be up roughly a third from 1985.

Several factors are responsible for the industry's much improved profitability. The decline in the cost of

Earnings rebound despite only modest growth in demand

energy and petrochemical feedstocks has been an important boon. The weakening of the U.S. dollar against the currencies of other major industrialized countries also has helped; since the dollar began to slip nearly two years ago the translation of overseas revenues into U.S. income statements has had a positive rather than a negative influence on the bottom line.

But more than anything else, the chemical industry's income statements have benefited this year from the massive restructuring of operations that took place in 1985 and, to a lesser degree, earlier. Plant closures, asset sales and write-downs, and reductions in management and professional staffs have drastically cut operating overhead, eliminated marginal operations, and trimmed excess capacity. As a result, this year, the industry has been operating more efficiently and productively than at any time in the recent past.

Comparing this year's earnings with those of the previous year can be misleading, to be sure. The huge write-offs and other nonrecurring charges that were part of last year's restructuring program abnormally and unexpectedly depressed earnings. The basic chemical industry was operating in the red during the second half of 1985, in fact, according to Census Bureau data. And many of the industry's leading firms reported a deficit for the year as a whole. To some degree, the extraordinary costs associated with restructuring can be excluded in making a comparison with this year, but not completely. So the gains in profits being reported this year are not really so strong as they may appear to be. Even so, profitability certainly is much more robust now than it was a year ago.

This year may be a hard act to fol-

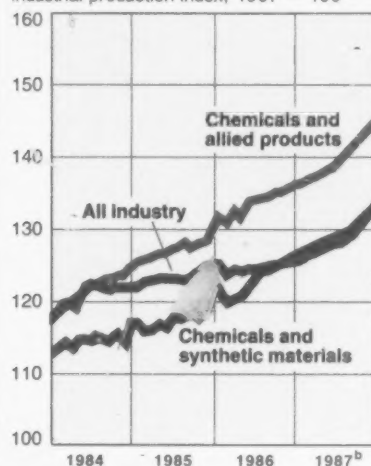
low, but next year, nevertheless, promises to be pretty much a replay of 1986. That, at least, seems to be the consensus among industry officials as the year draws to a close. Nobody really is looking for an upsurge in demand for chemicals. But further moderate expansion still looks like a good bet. And selling prices for chemicals have shown signs of being somewhat firmer lately, with some increases probable during the year ahead. In addition, the industry probably has not yet reaped all the benefits from its restructuring. Prospects look good, therefore, for a second year of much improved earnings for the industry—although the gains may be only about half as large as those being scored this year.

Because its customers are spread so widely throughout the U.S. economy, the chemical industry's performance hinges heavily on trends in the economy as a whole. And although a few economists are turning gloomy about the nation's economic outlook, a clear majority are still optimistic now, if only in a relatively moderate way. The prediction for next year is that gross national product will continue to expand at about the same rate as it has in the past two years, or perhaps just a bit more—thereby adding another year to a period of unprecedented economic stability.

If the overall rate of expansion manages to remain little changed, though, it is not likely that trends among the individual components of the economy will remain the same. During the past 12 months, the economy has been largely consumer driven. That is one reason why chemical production has outpaced that for all industry, since the bulk of the chemical industry's products ultimately wind up in the hands of consumers.

Production is climbing at a sluggish pace

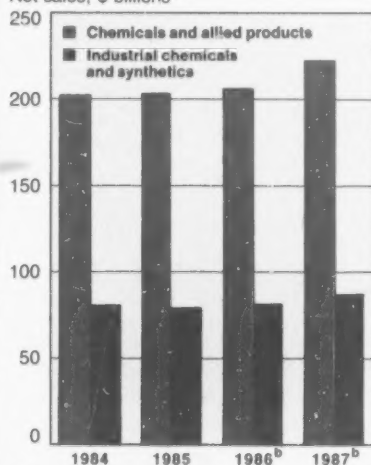
Industrial production index, 1967 = 100^a



^a Seasonally adjusted. ^b C&EN estimates. Source: Federal Reserve Board

Sales volume has been relatively flat lately

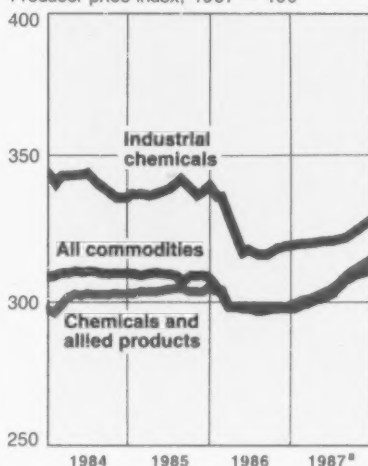
Net sales, \$ billions^a



^a Excludes sales of foreign subsidiaries. ^b C&EN estimates. Source: Bureau of the Census

A slow erosion of prices probably is ending

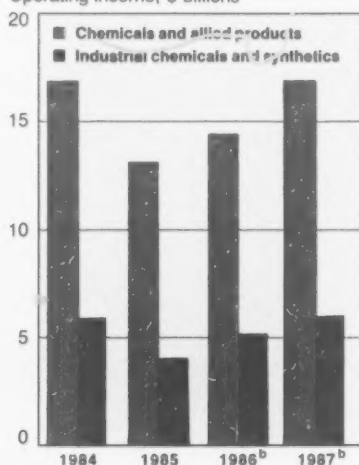
Producer price index, 1967 = 100



^a C&EN estimates. Source: Bureau of Labor Statistics

But profits are rebounding smartly at present

Operating income, \$ billions^a



^a Excludes nonoperating income and expenses and income taxes. ^b C&EN estimates. Source: Bureau of the Census

It will be surprising, though, if consumers continue to play such a dominant role. For one thing, consumer debt recently has been abnormally high and consumer saving has dwindled to an extraordinarily low level relative to income. Both can be expected to shift to more normal levels during the year ahead, leaving fewer dollars available to chase after consumer goods. This may be offset, at least in part, by money released into the economy by next year's lower tax rates, how-

ever. And as long as inflation stays in check—consumer prices will be up less than 2% this year, the lowest inflation rate in more than 20 years—and interest rates continue close to current low levels, consumer spending can be counted on to remain a strong factor behind expansion.

A slight gain in capital investment next year is likely to take up a bit of any slack that may develop in consumer spending. In addition, hopes are rising that a turnaround

now is taking place in the U.S. balance of foreign trade. The weakening of the U.S. dollar abroad has surprisingly done little or nothing to stem the flood of imports or generate higher exports from the U.S., in part because the prices of many imported goods have not risen as the dollar has fallen. But now there are a few tentative initial signs that the trade deficit may fall during 1987 (see page 27). In fact, the U.S. International Trade Administration is forecasting that it will shrink significantly. That would provide considerable support for the overall economy.

The chemical industry, in the meantime, already has witnessed some welcome improvement in its foreign trade, with exports this year up 4%. That bodes well for 1987.

For several key markets for chemicals and the products made from them, however, the outlook has become a bit more shaky.

The automotive market is one that is not expected to be quite so robust in 1987. Sales, by and large, have been strong for car producers, at least whenever they were temporarily pumped up by such sales incentives as price discounts or reduced debt carrying charges. But imported cars continue to eat away at Detroit's market share, accounting for about a third of sales recently.

Total output of cars in the U.S. consequently dipped to under 8 million from 1985's 8.2 million. Auto industry officials foresee a further decline in 1987. U.S. car sales now are being forecast to fall by as much as a million below the nearly 11.5 million sold this year, whereas imports probably will make further market gains. The upshot could be a 10 to 15% drop in U.S. production.

Housing is another market in which demand may ease slightly. New housing starts have been dwindling all year long, after hitting a two-year peak last January. Because they led off the year at a fast pace, total starts probably will hit 1.80 million to 1.85 million, 3 to 6% higher than in the previous year. That's the most for any year since 1978. But with no development in view to reverse the current trend downward, housing starts next year are likely to trail this year's total by

United States

about 200,000, a drop of more than 10%, putting a crimp in demand for plastics, fibers, and coatings.

Softening the blow a bit, however, is that most of the decline will be in multifamily buildings rather than single-family homes; a high rate of vacancies in existing apartments coupled with income tax reform that axes the tax shelter advantage of investing in housing developments is largely to blame. Meanwhile, the size of the average new single-family home—as well as its cost—has been increasing. In addition, makers of housing materials are winning sales from greater spending by homeowners to maintain and upgrade existing houses.

A cutback in home building next year also may bring a slowdown in growth for some other significant markets for chemical products. Appliance output, for example, is 8 to 10% higher this year, a rate of growth that is not likely to be matched in 1987. This year's 3% increase in furniture production likewise is unlikely to be repeated during the year ahead.

The textile industry, too, has benefited from the rise in home building. Increased demand for carpeting

and specialty fabrics, for one thing, has been a major factor behind this year's 5% increase in nylon output and 8% rise for polyolefin fibers. But rising imports continue to severely undercut U.S. production of fibers for clothing. Even so, 1986 has been a good year for textile mills compared with some in the immediate past. Next year, import restrictions and various industry programs aimed at encouraging the purchase of U.S.-made apparel may bring further growth in fiber demand.

The outlook remains bitterly bleak, on the other hand, for the U.S. agrochemical market. Excess production, dwindling exports, low prices, and financial crises have sharply curtailed farmers' purchases of fertilizers and pesticides. Government farm programs also have reduced the acreage of land being planted; U.S. farmers this year took 44 million acres out of production in exchange for government subsidies. Meanwhile, overseas markets for farm chemicals are shrinking as more of the world's developing nations turn to local production and farm surpluses increase abroad. The upshot is that U.S. production of ammonia, nitric acid, and phos-

phoric acid is down 15% or more. Pesticide markets, too, have been hit by increasing federal regulation.

Further reduction in farm acreage is slated for 1987, as the government strives to cope with huge carryovers of feed grains. And despite the weakened dollar, exports of fertilizers show no signs of improving. As a consequence, demand for fertilizer will drop once more, prices will remain weak, and profits in the agrochemicals business will be poor again in 1987.

Elsewhere in the chemical industry, however, although the outlook may not generate a wave of enthusiasm, it at least is encouraging. Spurred by an improving climate for foreign trade and another year of relatively strong consumer spending, production of chemicals, plastics, and fibers probably will be up 5 to 8%, with output in the broader chemicals and allied products industry rising 4 to 6%. Pricing will be less of a negative factor on revenues, as well. Sales consequently will be 5 to 10% higher than in 1986. And with costs in hand and plant efficiency improved, profits probably will rise again next year, perhaps 15 to 20% to a six-year high. □

Except for fertilizer materials, the outlook is moderately upbeat for chemical production

	1984	1985	1986	1987
INORGANIC CHEMICALS				
Thousands of tons unless otherwise indicated				
Ammonia	16,692	16,201	13,800	13,100
Chlorine gas	10,700	10,402	10,600	11,000
Hydrochloric acid	2,693	2,807	3,050	3,200
Nitric acid	7,726	7,778	6,500	6,200
Oxygen, billions of cu ft	387	393	405	420
Phosphoric acid	11,370	10,492	8,950	8,500
Sodium hydroxide	10,914	10,811	11,200	11,500
Sulfuric acid	41,802	39,615	36,500	35,400
ORGANIC CHEMICALS				
Millions of lb unless otherwise indicated				
Acetic acid	2,619	2,897	3,000	3,150
Acetone	1,862	1,788	1,900	1,950
Acrylonitrile	2,219	2,349	2,250	2,350
Benzene, millions of gal	1,318	1,283	1,320	1,370
Butadiene	2,452	2,340	2,500	2,600
Cumene	3,754	2,627	2,800	3,000
Cyclohexane	1,994	1,657	2,000	2,200
Ethylene	31,383	29,846	32,100	34,200
Ethylene glycol	4,823	4,178	4,400	4,600
Formaldehyde	5,815	5,606	5,800	6,000

	1984	1985	1986	1987
Methanol				
	8,186	5,003	5,600	6,100
Phenol				
	2,889	2,841	2,950	3,050
Phthalic anhydride				
	870	820	860	900
Propylene				
	15,559	14,887	17,000	18,200
Styrene				
	7,709	7,622	7,950	8,350
o-Xylene				
	688	675	750	780
p-Xylene				
	4,264	4,779	5,200	5,500
PLASTICS				
Millions of lb				
Polyethylene, high density	6,085	6,671	7,150	7,600
Polyethylene, low density	8,413	8,889	8,900	9,200
Polypropylene	4,940	5,139	5,700	6,050
Polystyrene	3,838	4,054	4,400	4,600
Polyvinyl chloride	6,760	6,772	7,200	7,400
SYNTHETIC FIBERS				
Millions of lb				
Acrylic and modacrylic	671	631	620	640
Nylon	2,412	2,343	2,470	2,550
Olefin and vinyon	997	1,249	1,350	1,420
Polyester	3,392	3,341	3,300	3,400

Sources: Bureau of the Census, International Trade Commission, Society of the Plastics Industry's Committee on Resin Statistics, Textile Economics Bureau, C&EN estimates (for 1986 and 1987)



FOREIGN TRADE

World trade in chemicals continues to expand, but currency exchange rates mask the extent of the growth this year

Earl V. Anderson, C&EN New York

Statistics on world chemical trade—always suspect because of the variety of sources and data systems from which they must be gleaned—are even more suspect this year. The problem is the drastic change in the dollar exchange rate.

Based on the most recent available data, world chemical trade, measured as exports, may hit a hefty \$184 billion this year, a surprising 20% more than in 1985. Given the less-than-robust economic conditions throughout the world, most chemical trade experts agree that a 20% gain in chemical trade is highly unlikely. A more plausible gain would be about 5%.

But drastic changes in monetary exchange rates can cause such statistical aberrations. From its peak in March 1985, the U.S. dollar has fallen more than 25% against a basket of 13 major foreign currencies, according to the Department of Commerce. Since the first of the year, it has dropped 11% against that same currency basket.

The sharply weaker dollar is great for those who had invested money in international mutual funds. It's not so great, however, for those who

With exports rising once more, U.S. chemical trade surplus shows small gain

have to compile international trade statistics.

Much of the difference between a dollar-based 20% rise in world chemical trade and a more rational 5% estimate lies in the chemical trade statistics of the 12-nation European Economic Community. On a dollar basis, EEC chemical exports likely will come close to \$100 billion this year, 25% higher than last year.

However, EEC officially reports its statistics in European Currency Units (ECUs). Actually, an ECU is a "basket" unit, based on a certain quantity of the currency of each member nation and weighted according to gross national product and trade. In ECUs, chemical exports from EEC countries ran only 4% higher than last year through the first six months. Meanwhile, there are about 20% more dollars per ECU this year than there were last year.

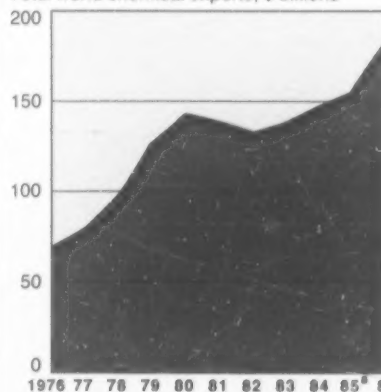
The same situation exists for Japanese chemical exports, because the yen has appreciated so much against the dollar. This year, for instance, Japanese chemical exports will be up 22% if the dollar is the yardstick. They will be down 14%, however, if the yen is used as the measure.

But even on a dollar basis, Japanese chemical exports will be only about \$9.4 billion this year, roughly 5% of the world total. However, as a block, EEC is by far the world's largest chemical exporter, with a commanding 55% of the world market. Thus, if its chemical exports are really up only 4% whereas the exchange rate between ECUs and dollars has changed almost 20%, this year's growth in world chemical trade can be misleading when all of the pieces are converted to dollars.

For U.S. chemical producers, this statistical malfeasance is unfortu-

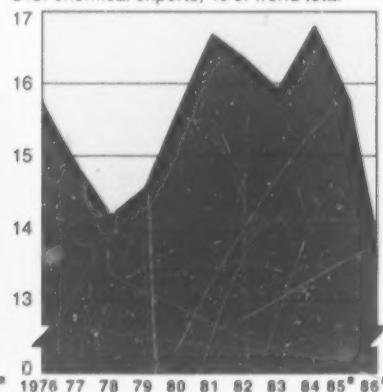
World trade in chemicals is sharply higher ...

Total world chemical exports, \$ billions



... but U.S. share of the total plunged recently

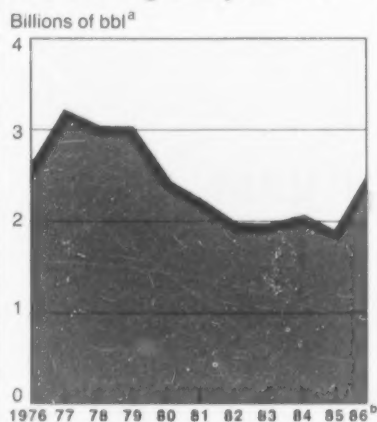
U.S. chemical exports, % of world total^b



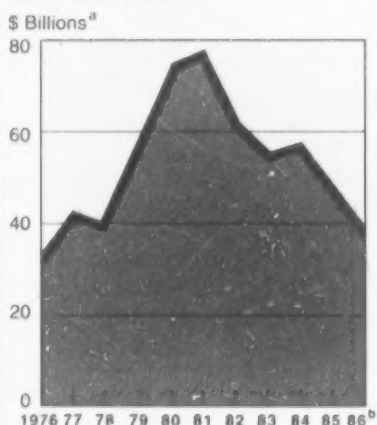
^a C&EN estimates. ^b Defined as U.S. chemical exports as per cent of world chemical exports less U.S. chemical imports. Sources: United Nations, Bureau of the Census

Foreign Trade

U.S. imports of oil are rebounding this year ...

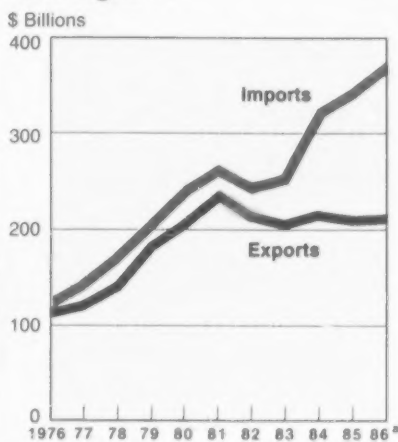


... but lower prices keep their cost down



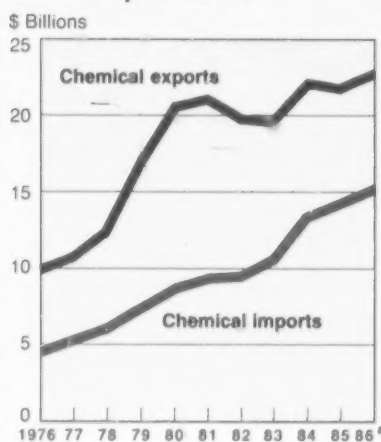
^a All petroleum products. ^b C&EN estimates.
Source: Bureau of the Census

Overall U.S. trade deficit hits new highs ...



^a C&EN estimates. Source: Bureau of the Census

... but the slide in chemical trade surplus ends



nate, because it detracts somewhat from their otherwise satisfying trade performance in 1986. Based on exchange rate arithmetic, U.S. chemical exporters will lose a substantial share of the world market this year, when more than likely, they will maintain or slightly increase their share.

Not that this year's 4% increase in U.S. chemical exports is all that impressive. But compared with last year's 3% drop, it's not bad.

Besides, this year's \$22.6 billion worth of overseas shipments sets a new record for U.S. chemical exports, breaking the old high set two years ago. Meanwhile, chemical im-

ports are being held to a similar 4% advance, half of last year's increase.

Thus, chemical imports will weigh in at about \$15.1 billion by year's end. That, too, is a new record, but it signals a welcome end to the five-year slide in the U.S. chemical trade surplus. That surplus hit \$12.1 billion in 1982, but it has slipped every year since then. Last year, it bottomed out at \$7.2 billion.

This year, the U.S. chemical trade surplus should inch back up to \$7.5 billion. After watching the strength ebb out of the dollar for more than a year and a half, that performance may not be so good as some chemical traders had expected. But it cer-

Plastics, organic chemicals, and pharmaceuticals lead growth in U.S. chemical exports

\$ Millions	U.S. chemical exports				U.S. chemical imports			
	1986 ^a	1985	1984	1983	1986 ^a	1985	1984	1983
Organic chemicals	\$ 6,305	\$ 6,012	\$ 6,093	\$ 5,326	\$ 4,790	\$ 4,576	\$ 4,265	\$ 3,477
Plastics and resins	4,317	3,777	4,050	3,732	1,903	1,631	1,484	1,098
Medicinals and pharmaceuticals	3,096	2,708	2,628	2,494	1,225	1,084	931	703
Fertilizers, manufactured	1,876	2,160	1,815	1,267	936	967	1,142	997
Inorganic chemicals	1,763	1,967	2,184	1,838	1,965	1,948	2,064	1,615
Radioactive materials	1,130	1,311	1,421	1,213	1,195	1,417	1,394	952
Pesticides and disinfectants	700	614	707	630	433	399	308	251
Flavors, perfumes, cosmetics, and toiletries	497	478	498	493	861	577	521	370
Pigments, paints, and varnishes	340	322	335	328	347	266	232	145
Cleaning and polishing materials	294	292	308	295	24	172	118	90
Dyeing, tanning, and coloring materials	158	139	158	163	483	352	358	300
Explosives and pyrotechnics	90	100	146	87	106	103	84	64
Miscellaneous	2,034	1,878	1,992	1,885	831	1,005	797	717
TOTAL	\$22,600	\$21,759	\$22,336	\$19,751	\$15,100	\$14,533	\$13,697	\$10,779

^a C&EN estimates. Source: Bureau of the Census

Foreign Trade

With exports little changed, higher manufactured imports increase U.S. trade deficit

\$ Billions	U.S. exports				U.S. imports			
	1986 ^a	1985	1984	1983	1986 ^a	1985	1984	1983
Chemicals	\$ 22.6	\$ 21.8	\$ 22.3	\$ 19.8	\$ 15.1	\$ 14.5	\$ 13.7	\$ 10.8
Machinery and transportation equipment	93.8	94.3	90.0	82.6	159.6	137.3	119.2	86.1
Other manufactured goods	30.1	29.3	30.8	30.0	104.6	95.0	88.6	66.5
Food and live animals	16.9	19.3	24.5	24.2	21.0	18.6	18.0	15.4
Beverages and tobacco	2.6	3.0	2.9	2.8	3.6	3.7	3.7	3.4
Mineral fuels, lubricants, and related materials	8.2	10.0	9.3	9.5	40.1	53.9	61.0	58.0
Crude materials (inedible) other than fuels	16.5	16.9	20.2	18.6	10.7	10.4	11.1	9.6
Animal and vegetable oils and fats	1.1	1.4	1.9	1.4	0.5	0.7	0.7	0.5
All other products	10.7	11.0	10.1	7.0	14.8	11.1	9.8	7.7
TOTAL	\$214.3^b	\$213.1^b	\$217.9^b	\$200.5^b	\$370.0	\$345.3	\$325.7	\$258.0

^a C&EN estimates. ^b Includes re-exported imports (not included in individual product categories). Source: Bureau of the Census

tainly is better than the overall U.S. trade picture. By now, "trade deficit" has become almost a household phrase and most households know that the U.S. is heading for yet another record trade deficit.

Most reliable estimates have this year's deficit topping \$170 billion, up from last year's \$148 billion. These numbers are based on imports figured on a c.i.f. (cost, insurance, and freight) basis.

The older, more conventional way to figure trade balance is to compare exports with imports valued on a f.a.s. (free alongside ship) basis. Using this approach, the U.S. trade deficit this year will be "only" \$156 billion, 18% higher than 1985's \$132 billion. That may be easier on the eye than the c.i.f. trade deficit, but it is no easier to swallow.

Behind the swelling U.S. trade deficit are U.S. exports that barely managed to creep ahead less than 1% to \$214 billion this year, while imports grew faster than they did last year. The 7% growth in imports puts them at a record \$370 billion.

This turn of events has frustrated U.S. trade officials, especially since they cannot blame increasing prices for U.S. oil imports for the higher trade deficit. Imports (of all petroleum products) are going up—from 1.8 billion barrels last year to a bothersome 2.4 billion bbl this year. But the import price tag will drop to \$37.5 billion, 22% lower than last year.

Unfortunately, most of the fault lies in the trade of manufactured goods. Despite the drop in the dollar's value, the U.S. trade stance in manufactures has worsened.

U.S. exports of manufactured products, classified in three major trade categories, barely increased this year. Yet imports of these same three categories of manufactures are rising 14%. This trade alone accounts for \$140 billion of this year's \$156 billion total U.S. trade deficit.

It was not supposed to happen this way. According to economic theory, the weaker dollar is supposed to spur exports, lower imports, and reduce the trade deficit.

In the past few months, there have been indications that this is exactly what is happening. Exports have perked up and import growth has tapered off. The trade deficit is improving.

But why did it take so long? There is no shortage of possible explanations. One is the "J-curve" effect on imports, particularly from Japan and Europe. Although the falling dollar should reduce imports by making them more expensive, these higher prices increase their dollar value before volume falls far enough to make a difference.

Another explanation is that the dollar may not have fallen so much as the government claims it has. The decline in the dollar's value can vary, depending upon which currencies are used in the comparison basket and what kind of weighting is given to each currency.

The Federal Reserve Board index of the dollar's value against major industrial country currencies pegs it at 7% above its 1981 level. But economists say that this figure doesn't give enough weight to the currencies of Canada and major newly industrialized countries. The dollar

hasn't fallen against these currencies. Using a basket of 44 foreign currencies, Morgan Guaranty Trust calculates that the value of the dollar is still 50% above its 1981 level.

Finally, there are those who claim that U.S. industry simply is not competitive in world markets. U.S. industrial competitiveness has received a lot of attention lately. It is certain to receive much more in the next few years. □

U.S. chemical exports higher in most big foreign markets

\$ Millions	1986 ^a	1985
U.S. CHEMICAL EXPORTS		
Canada	\$ 2,757	\$ 2,698
Latin America	3,932	3,681
Western Europe	7,052	6,742
Eastern Europe	384	368
Japan	3,028	2,908
Australasia	678	704
Communist Asia	407	513
Middle East	339	400
Rest of Asia	3,300	3,023
Africa	429	456
Other	294	265
TOTAL	\$22,600	\$21,759

U.S. CHEMICAL IMPORTS		
Canada	\$ 2,893	\$ 2,913
Latin America	1,027	1,216
Western Europe	7,293	7,118
Eastern Europe	393	380
Japan	1,812	1,412
Australasia	226	231
Communist Asia	166	163
Middle East	241	218
Rest of Asia	604	457
Africa	257	203
Other	242	222
TOTAL	\$15,100	\$14,533

^a C&EN estimates. Source: Bureau of the Census



WESTERN EUROPE

**Lower feedstock costs
and capacity cutbacks
help offset impact of
import competition and
weakening prices**

Dermot A. O'Sullivan, C&EN London

Summarizing the present state of the chemical industry in Western Europe, Heinz Klaar draws an analogy with the popular winter sport in his native Netherlands. "We are skating on beautiful ice, but it is rather thin," says the vice president of Shell Chemical International Trading Co.

What Klaar is saying, in effect, is that European petrochemical firms, in particular, will come through this year in reasonably good business shape. Unless something unexpected happens, the same pattern will be maintained in 1987.

Both positive and negative factors have shaped Europe's economic climate, although their effects are complex and frequently counteracting. Most notable this year were the impact of a continuing slide in the U.S. dollar's value against major European currencies, and the drop in crude oil prices.

Between January and September this year, the dollar lost 16% of its value against the West German mark, 15% against the Italian lira, 11% against the French franc, and a more modest 3% against the U.K. pound sterling. Indeed, the plunge in the dollar that set in early last

Growth is spotty but chemical operations hold at a relatively high level

year may go yet further before leveling out.

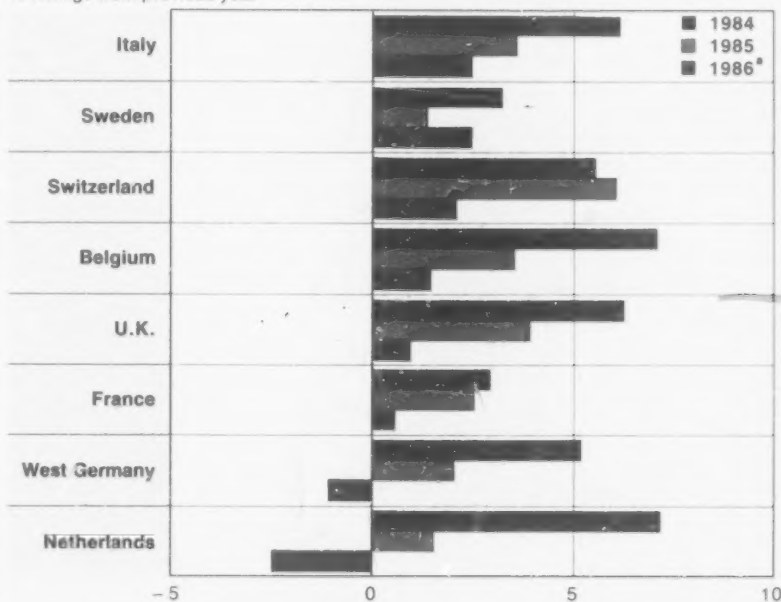
February 1985 marked the peak of the dollar against the U.K. currency, when it climbed 44% above its value against the pound in January 1983. In the case of the French, West German, and Italian currencies, the dollar reached its exchange rate peak in March 1985.

One positive effect of the lower dollar on European companies is a cut in interest payments, in local currency terms, due on their dollar-denominated debts. On the negative side, European-made goods are encountering stiffer competition from U.S. products sold in Europe and in dollar trading zones.

Sales and profit figures recorded in dollars also appear lower when translated into the currency of the European parent companies. Hermann-Josef Strenger, chairman of West Germany's Bayer, for example, noting the 12% decline in worldwide sales of his company (reported in deutsche marks) during the first nine months of this year compared with last year, says that currency fluctuations alone were responsible for a drop of 11%. Likewise, Wolfgang Hilger, chairman of Frankfurt-based Hoechst, says that more than half of the 15.4% fall in Hoechst's sales outside West Germany between January and September resulted from currency translation.

Growth generally eases for chemical production

% change from previous year



■ Estimated. Source: National chemical federations for each country

For Imperial Chemical Industries (ICI), based in London, the effects of varying exchange rates are more complex. The strengthening of the pound against Australian, Canadian, and U.S. currencies was offset to a degree by sterling's weakening against the deutsche mark and other European currencies. The net result was a 4% decline in the value of ICI's sales, in pounds, in this year's first nine months from that during 1985's like period.

On a more positive note, the weaker dollar has meant that dollar-priced oil, both for energy and as a source of chemicals, has become less expensive for Europeans. Coupled with this, of course, is the fall in the price of oil itself. The spot price of oil dropped from about \$26 a barrel last December (which, in turn, was down from nearly \$40 in 1980) to below \$10 this past July. It since has rebounded to the \$14 to \$15 range. The Organization of Petroleum Ex-

porting Countries (OPEC), at the urgings mainly of Kuwait and Saudi Arabia, is talking about raising the price of oil to \$18 a bbl or more. But when that will come about is anybody's guess.

Some observers maintain that Saudi Arabian petrochemical plans in particular are being negatively affected by lower-than-anticipated oil production, resulting in less availability of associated gas for feedstock. Moreover, they argue, the competitive edge of Saudi products has been dented somewhat. This could explain the switch to high-density polyethylene in preference to linear low-density polyethylene—which calls for C₄ or C₆ α-olefin comonomer that must be imported—in units capable of making either polymer.

Indeed, in Europe itself, analysts now are reworking their forecasts for the relative market trends of conventional LDPE and LLDPE in

light of the lower energy costs. And there is the added factor that LLDPE has not been particularly welcomed on the European market, as John N. Turnbull, BP Chemicals' director responsible for polymers, points out—even though his company started up a 220 million lb-a-year dual-purpose HDPE/LLDPE unit based on its own gas-phase technology earlier this year at Lavera in the south of France.

"Converters found that LLDPE was difficult to process," he admits. "It requires more energy than LDPE to extrude, and machinery had to be modified or replaced. Furthermore, the advantages of down-gauging [film thicknesses] often could not be realized. So despite the high level of imports from Saudi Arabia last year, penetration of the LDPE market in Europe by LLDPE is well below that in the U.S."

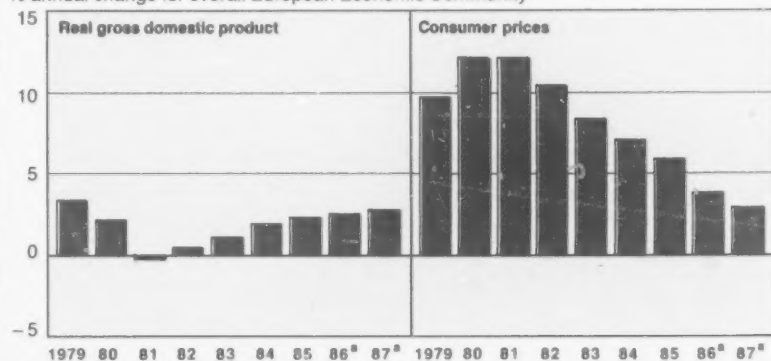
David Oxley, a director leading polymer studies at Chem Systems International's London office, agrees. He notes that LLDPE accounted for less than 10% (902 million lb) of the 9.5 billion lb of combined LDPE and LLDPE used in Europe last year. In the U.S., by comparison, LLDPE's share was about 39% (3.2 billion lb) of the corresponding total of 8.2 billion lb of polyethylenes consumed in 1985.

"Maybe the old high-pressure LDPE process that needs no comonomers or solvent, and produces pellets on a simple extruder, is not obsolete," he conjectures. "Certainly, power use is higher than for LLDPE, but it can be reduced by use of new polymerization initiators, low-energy pumps, and improved heat-recovery systems. And energy may not be so important a factor in a low-oil-price scenario."

Oxley foresees consumption of other commodity plastics—HDPE, polypropylene, and polyvinyl chloride, for example—also growing faster in Europe if the current relatively low oil price continues. HDPE demand, for instance, might advance 3.1% annually between 1985 and 1995 from the 4.1 billion lb used last year, as opposed to the 2.2% rate he thinks likely if oil rises to \$18 a bbl or higher. Likewise, polypropylene might move ahead at 4.8% a year (from the 4.5 billion lb

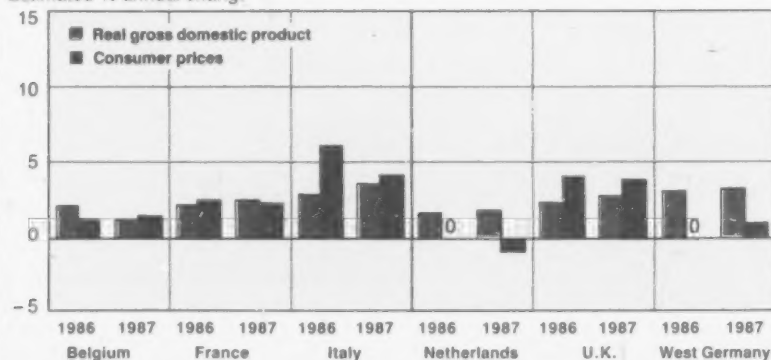
Economic expansion accelerates as inflation eases . . .

% annual change for overall European Economic Community



. . . with West Germany and Italy setting the growth pace

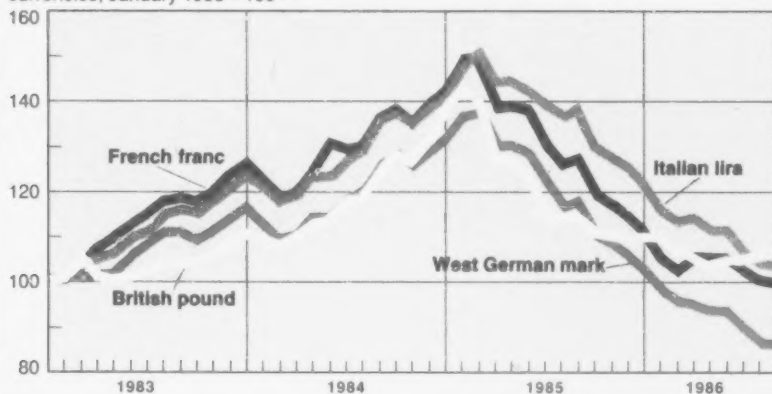
Estimated % annual change



Estimates. Source: Commission of the European Communities

Value of dollar in a tailspin in Western Europe

Relative value of U.S. vs. major Western European currencies, January 1983 = 100



Source: International Monetary Fund

consumed in 1985) instead of at a 3.8% rate. And PVC could achieve a 2.6%-a-year growth over the next 10 years (from last year's 8.8 billion lb), as against a 1.6% rate.

Tom O. Hutchison, ICI's director responsible for petrochemicals and plastics, admits that "an increasing number of oil industry pundits are putting their money on the oil price remaining at or around the \$15-per-bbl level for some time. Although OPEC is likely to re-establish greater influence in the 1990s," he says, "I believe that future price increases will be progressive rather than discontinuous. The prospects, at least for the next few years, are for oil to be principally influenced by a freer market than we have seen recently. As a result, we will have to live with oscillations in oil and gas prices.

"An unfortunate consequence of price instability is the danger that petrochemical selling prices will be reduced quickly as feedstock prices weaken, but will rise more slowly when they rebound," he warns. "Producers need to exercise sound commercial judgment in order to preserve profit margins."

A spinoff of the oil price decline is that oil and gas activities in the North Sea are being wound down. This has a sharp impact on related industries, and on the economies of the areas they operate from, in Norway and the U.K. particularly. Faced with canceled contracts and declining orders, companies are shedding

large numbers of their labor force, thereby adding to an already critical unemployment situation throughout Western Europe.

Indeed, unemployment is the key issue that European Economic Community officials in Brussels are grappling with. It averages almost 12% of the labor force throughout EEC. Spain has the highest rate (about 22%), with Ireland not far behind at 18%. Those with lower double-digit unemployment figures are Belgium (13%), France (10%), Italy (13%), and the Netherlands and the U.K. (each 12%).

Critical unemployment levels notwithstanding, the annual report of the Commission of the European Communities shows some encouraging signs of the state of EEC's overall economy and is generally optimistic for the immediate future. The average inflation rate has come down year by year from its 1981 high of 12.1% to the current estimate of 3.5%. Next year, it might fall further to 3%. At the same time, gross domestic product has been undergoing a steady advance.

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"Economic recovery in the community is continuing," the report notes. "Private consumption and investment are the strongest growth elements. Lower price increases and interest rates are improving medium-term growth prospects."

Since January, Portugal and Spain have been full members of EEC, bringing to 12 the number of countries in the community. (The others are Belgium, Denmark, France, Greece, Ireland, Italy, Luxembourg, the Netherlands, the U.K., and West Germany.) Their entry raises EEC's population to more than 320 million from around 275 million.

Changes in chemical production this year don't appear too exciting, on the other hand. Of the countries C&EN polled, Italy, Sweden, and Switzerland show the best output gains relative to 1985, up more than 2%. The U.K.'s chemical output will be up about 1%. France's slim 0.6% advance reflects weakness in fertilizers and the basic mineral products associated with it and of dyes, both of which have retreated 8% from their 1985 levels. Output of fragrances didn't grow. Neither did that of specialties, mainly because of a slowdown in agrochemicals. Best performers were pharmaceuticals (up 6%) and plastics (up 5%).

For West Germany and the Netherlands, chemical output this year will be less than in 1985. But a spokesman for the West German Chemical Industries Association cautions against taking his country's figures too much at face value, noting that 1986 hasn't been that bad considering the good performance in 1985. As he puts it, "If you're driving at 100 miles an hour and you slow to 90, you're still moving pretty fast."

Chemical prices across the board have weakened, meanwhile. In West Germany, the chemical price index in September was 6.5% below January's level and down 8.5% from September 1985. In Italy, likewise, the decline was 5.4% during the first nine months and 7% since September of last year. U.K. chemical producers managed a meager 0.2% gain in prices between September 1985 and September this year, although prices retreated 1.4% during the first nine months. In France, the price

index is down about 1%, reflecting the oil price drop.

Chemical managers are countering the pressure on prices by running their operations more efficiently and closer to capacity. They are helped in this by the rationalization steps that have been taking place during the past few years in the effort to bring overall capacities closer into line with demand, spurred by the very heavy financial losses they were experiencing. Nameplate capacity of LDPE, for instance, has been reduced 19% since 1980 to about 11 billion lb and that of general-purpose and high-impact polystyrene 17% to some 4 billion lb.

Phaseout of uneconomic crackers has brought Western Europe's ethylene capacity down 13% since 1980 to around 31 billion lb annually. That's only 10% or so beyond consumption, now about 28 billion lb a year.

Commenting on cracker capacities, Jean François Berthiaux, marketing director for basic chemicals at Exxon Chemical International in Brussels, believes "there's a lot more supply capability in the world than you usually see in compilations. Significant increases can and do result from minor efficiencies and debottlenecks that are unannounced and unreported."

"Our assessment shows that these efficiencies account for a worldwide ethylene capacity increase of be-

West Europe slashes petrochemical capacity

Billions of lb	Year-end capacity		% change
	1986	1980	
Ethylene	31.0	35.6	-13%
Ethylene oxide	3.9	4.6	-14
Polyethylene, high density	5.7	5.6	—
Polyethylene, low density	10.9	13.5	-19
Polypropylene	6.3	4.7	33
Polystyrene ^a	4.1	4.9	-17
Polyvinyl chloride	11.1	12.0	-7

^a General-purpose and high-impact polymer.
Source: C&EN estimates

tween 1 and 2% a year. That translates into a capacity addition of one world-scale cracker each year." He reasons, therefore, that there is no need for new ethylene plants in the industrialized world before the end of the next decade.

There is some concern about the likelihood that propylene might become tight in Western Europe in view of the projected growth seen for polypropylene production. Shell's Klaar expects the olefin will lose some of its cost advantage relative to ethylene. He also foresees the U.S. becoming a more important supplier of propylene and its derivatives to Europe than it has been.

Elsewhere in the West European chemical arena, synthetic fibers' performance has been down somewhat. Output of acrylic, polyamide, and polyester fibers has declined 3 or 4% from last year to levels only marginally ahead of 1984.

Worse off, by far, are fertilizers, which have been adversely affected by a number of factors. One of these was poor weather conditions during the opening months of the year. Another is that farm incomes, generally, have been depressed. Aggravating the situation for local producers were increased shipments of low-priced urea into Europe.

The EC Commission is looking at urea exported by Czechoslovakia, East Germany, Kuwait, Libya, Saudi Arabia, the Soviet Union, Trinidad and Tobago, and Yugoslavia in an antidumping investigation that was launched at the behest of the European Council of Chemical Manufacturers' Federations (CEFIC). Imports

from these eight countries have grown more than 10-fold in the past two years—1.86 billion lb during the 1985-86 fertilizer season compared with 156 million lb two years earlier, according to CEFIC—and now account for about 25% of EEC's urea fertilizer market.

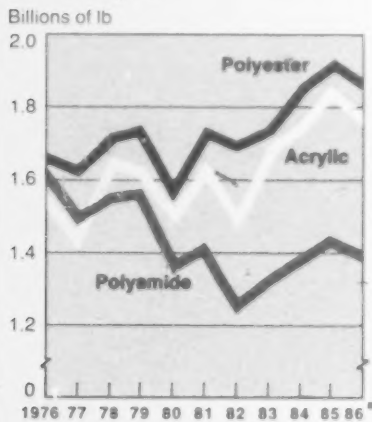
There still seem to be opportunities for chemical companies to make money in the agricultural sector, however. "We forecast a good future for agricultural chemicals in Europe," Du Pont says, "following our round of acquisitions and joint ventures in the crop protection area and introduction of the first members of our new sulfonyleurea herbicides."

To strengthen their competitive position in the marketplace, European chemical concerns continue to reshape their own organizations and link up with others. ICI, for instance, has merged four mainstream chemical businesses into a single entity with sales of about \$5 billion annually. Called ICI Chemicals & Polymers, it brings together the company's activities in catalysts, chlorine and its derivatives, mineral products, petrochemicals, plastics, and surface coatings when it officially becomes operational Jan. 1.

During the past year, ICI agreed with Enka, the fibers arm of AKZO of the Netherlands, to acquire Enka's nylon 6 interests in exchange for its commodity polyester staple operations, except those in Portugal and Spain. It also formed a joint venture with Italy's Enichem that pools the polyvinyl chloride activities of both and now trades as European Vinyls Corp. By phasing out excess capacity and trimming personnel, the new firm will be in a better position to turn a profit in place of the losses of the partners in their PVC businesses.

Atochem of France and BP Chemicals, too, have linked up. They are consolidating their polypropylene operations in Appryl, a new venture owned 51% by Atochem and 49% by BP. The new company has two production sites in France. When expansions are completed in 1988, Appryl, with an annual capacity of 550 million lb, will rank fifth among Western Europe's polypropylene producers. □

Growth stalls for European fiber output



■ Estimates. Source: CIRFS (International Rayon & Synthetic Fibers Committee)



JAPAN

Faltering economy, export slump, import competition bedevil short-term outlook for chemical industry

Earl V. Anderson, C&EN New York

"Another year of struggle." That's how one Japanese chemical company executive describes this fiscal year for the Japanese chemical industry. What he worries about now is whether he will have to use that same phrase when it comes time to describe fiscal 1987.

That's entirely possible, unless the government's plan to stimulate the economy does more than skeptical industry leaders expect it to. At the end of October, the Bank of Ja-

pan trimmed its official discount rate to a postwar low of 3%—the fourth cut in that key rate since January.

Behind the rate cut lies a faltering Japanese economy and the deflationary impact of a sharply appreciating yen. The yen, which stood at almost 260 to the U.S. dollar at the beginning of 1985, fell to 200 by the end of the year. It dropped further to 162 early this month.

As a result, export-oriented companies in Japan have cut back production and reduced capital investment. Some have even eliminated jobs, which is rare in Japan.

One unmistakable measure of the economic problems facing Japan's manufacturers: Nissan Motor Co., Japan's leading auto maker, suffered an operating loss of 19.7 billion yen (about \$120 million) during the first half (April to September) of fiscal 1986. It was the company's first loss since it was list-

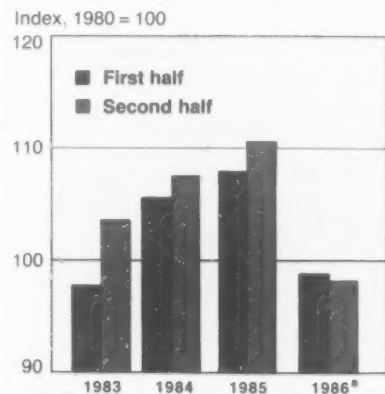
ed on the Tokyo Stock Exchange in 1951.

The strong yen has spread its economic carnage among Japanese chemical companies as well. A C&EN survey of 16 Japanese chemical companies shows that, as a group, these companies suffered a drop of 8% in sales and 17% in net income during their first fiscal half, which ended Sept. 30, compared with the first half of fiscal 1985. Of these 16 companies, 13 had lower sales and 11 lower net income.

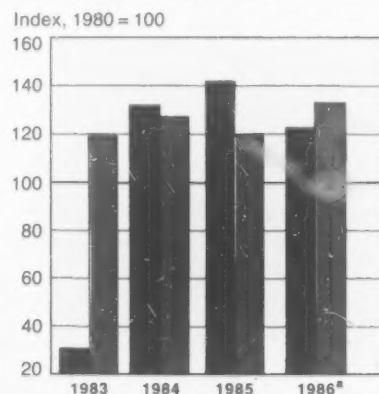
For a half-dozen of these companies, in fact, the profit slump ranged from 30 to 60%. Among the big losers were Unitika, Toray, Teijin, and Kuraray. These four are all major synthetic fiber and textile companies. All put a major part of the blame on a sharp drop in exports. The higher value of the yen has made them uncompetitive in many export markets, particularly with exports from developing countries.

Profitability improves for Japanese petrochemical producers

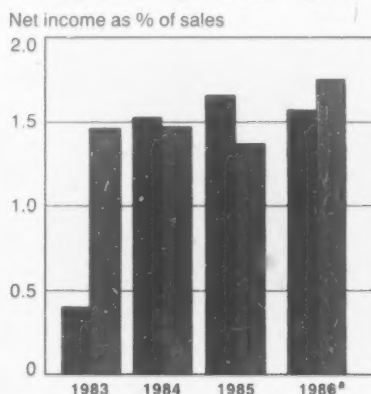
Despite lower sales this year . . .



. . . net income holds up . . .



. . . as profit margins edge higher

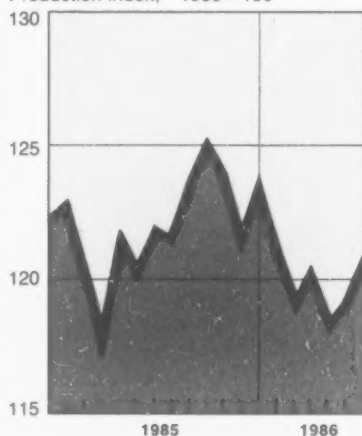


Note: Based on results of 10 leading Japanese chemical companies: Asahi Chemical Industry, Dainippon Ink & Chemicals, Mitsubishi Chemical Industries, Mitsubishi Petrochemical, Mitsui Toatsu Chemicals, Sekisui Chemical, Showa Denko, Sumitomo Chemical, Teijin, and Toray Industries. For most, but not all of these companies, the fiscal year ends March 31 of the following year. * Estimated. Source: Toyo Keizai Shinposha

Sluggishness haunts Japanese chemical production

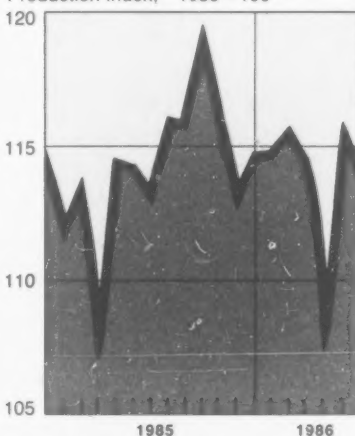
All chemicals

Production index,^a 1980 = 100



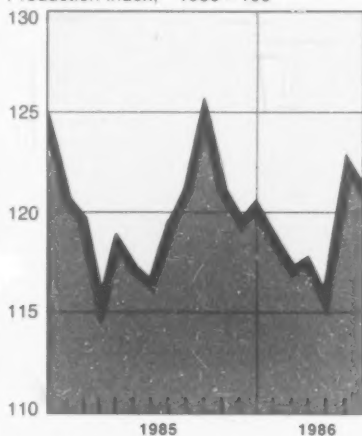
Petrochemicals

Production index,^a 1980 = 100



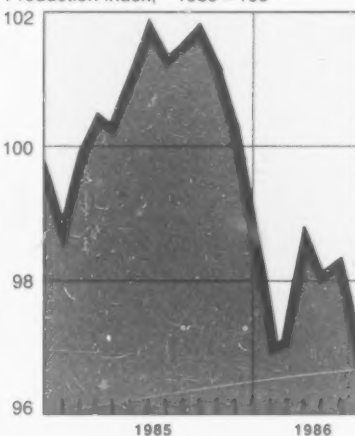
Plastics

Production index,^a 1980 = 100



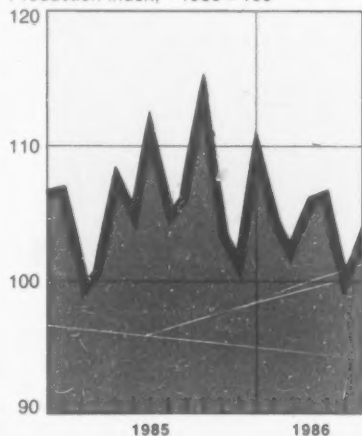
Synthetic fibers

Production index,^a 1980 = 100



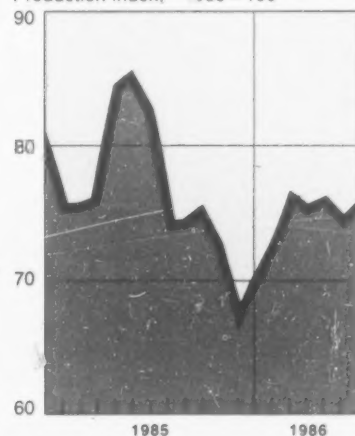
Synthetic rubber

Production index,^a 1980 = 100



Fertilizers

Production index,^a 1980 = 100



^a Seasonally adjusted. Source: Ministry of International Trade & Industry

In fact, the strong yen has affected the entire spectrum of Japan's chemical trade. If the country's chemical trade is looked at in terms of dollars, chemical exports probably will rise 22% this year (to \$9.4 billion) and imports will increase 18% (to \$9.5 billion).

Looking at the same chemical trade in yen, however, gives an entirely different picture. In yen, Japanese chemical exports will be down 14% this year, and imports will be off about 16%. The drop in imports reflects a weaker domestic economy, but this weaker economy is also a consequence of the strong yen. When Japanese exports of cars, household electrical appliances, and other big-ticket items decline, then domestic demand for the chemicals and plastics that go into them also goes down.

Not all Japanese chemical exports have been adversely affected by the strong yen, however. Exports of general-purpose resins, with the exception of polypropylene, have been higher this year than in 1985.

There are several reasons for this. First, with demand sluggish in their domestic market, producers have more resin available to export. In addition, less competitive material seems to be moving into Japan's all-important Southeast Asian market from the U.S., Europe, and even Saudi Arabia. Finally, several Japanese manufacturers of household appliances and other equipment that use plastics have moved their production out of Japan into other countries. These companies still use Japanese resin, however.

In Japan itself, however, petrochemical imports continue to peck away at the Japanese domestic market. Saudi Arabian polyvinyl chloride started arriving in Japan this year. Producers expect as much as 50,000 metric tons of it to reach Japan in 1986.

Methanol from Saudi Arabia and other countries has been moving into Japan for some time now, as well. Japanese producers can't compete with these imports, and production has slumped from more than 2 million metric tons in the early seventies to 254,000 metric tons last year. It will be less than that this year.

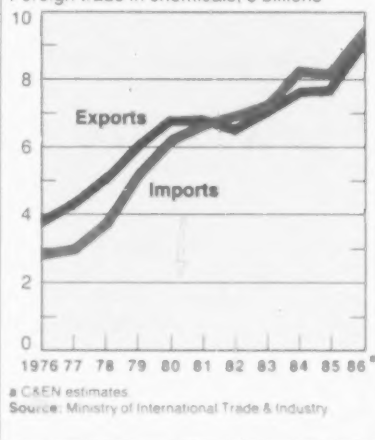
In fact, methanol production soon may be all but phased out in Japan. Mitsui Toatsu, one of only two remaining producers, will scrap all of its capacity except for 55,000 metric tons, which it will use captively. Mitsubishi Gas Chemical, the other producer, will trim its capacity 50 to 60%. Both will turn to imported methanol from Saudi Arabia, Canada, and from countries such as Indonesia and Burma that have just started up production.

Even inorganics, such as caustic soda and soda ash, are being imported increasingly into Japan.

Because of the long-anticipated decline in Japan's basic petrochemical fortunes, Japanese chemical companies are emphasizing diversification into higher-value-added products. Many of Japan's leading chemical companies have been pursuing this strategy for some time. But the impact of the strong yen has given them a new sense of urgency. Specialty plastics, ceramics, pharmaceuticals, and bioengineered products are among the most popular targets.

Balance in chemical trade remains narrowly in the red

Foreign trade in chemicals, \$ billions



Japan's Ministry of International Trade & Industry is encouraging companies to develop ceramics know-how. Sumitomo Chemical is one chemical company that is doing just that. Sumitomo is working on technology to make silicon carbide/

aluminum nitride powders and other ceramic products. Its fine ceramics business, says the company, is "moving into high gear."

Meanwhile, Mitsubishi Chemical Industries is beefing up its engineering plastics business. And Shinetsu Chemical is building a rare-earth refinery that is scheduled to be on stream next March.

Mitsui Petrochemical Industries, meanwhile, is building a new research laboratory designed specifically to develop specialty chemicals. And the company is planning to follow Japanese car makers to the U.S., where it will produce thermoplastic elastomers and other specialties for the automotive market.

Moving into higher-value-added products, however, is a long-term strategy and may not do much to help Japanese chemical companies next year. Private economists in Japan think the cut in the discount rate came too late to help the economy much, if at all. If so, Japanese chemical companies are in for another "year of struggle" next year. □

Chemical production in Japan generally is down this year

Thousands of metric tons unless otherwise indicated

	1985	1986	1985	% change
INORGANIC CHEMICALS				
Ammonia	1981	1061	1177	-10
Ammonium chloride	373	213	225	-5
Ammonium sulfate	1837	1046	1082	-3
Calcium carbide	441	257	282	-9
Calcium superphosphate	529	315	329	-4
Carbon black	632	366	368	-1
Chlorine, liquid	926	528	552	-4
Hydrochloric acid	549	318	319	0
Nitrogen ^a	6220	3673	3642	1
Oxygen ^a	7388	3986	4317	-8
Sodium carbonate	1057	589	621	-5
Sodium hydroxide	3075	1779	1807	-2
Sodium silicate	594	338	335	1
Sulfuric acid	6580	3900	3897	0
Titanium dioxide	217	132	127	4

ORGANIC CHEMICALS

	1985	1986	1985	% change
Acetaldehyde	271	146	157	-7
Acetic acid	344	165	191	-14
Acetone	237	129	134	-4
Acrylonitrile	541	317	311	2
Benzene ^b	2084	1180	1172	1
Butadiene	639	382	364	5
Butanol	258	137	142	-4
Caprolactam	455	263	267	-1

Thousands of metric tons unless otherwise indicated

	1985	1986	1985	% change
Cyclohexane	524	305	311	-2
Dioctyl phthalate	241	147	141	4
Ethylene	4224	2418	2479	-2
Ethylene dichloride	1901	1077	1105	-3
Ethylene glycol	440	209	255	-18
Ethylene oxide	554	295	323	-9
Methanol	254	131	151	-13
Octanol	230	124	126	-2
Phenol	262	145	146	-1
Phthalic anhydride ^b	162	89	95	-6
Propylene	2980	1761	1703	3
Propylene glycol	219	123	121	2
Styrene	1418	793	811	-2
Terephthalic acid	854	531	466	14
Toluene	803	466	446	4
Toluene diisocyanate	84	46	46	0
Urea	929	500	614	-19
Xylene	1523	881	841	5

PLASTICS

	1985	1986	1985	% change
Phenolic resins	325	182	196	-7
Polyethylene	2027	1159	1154	0
Polypropylene	1304	753	738	2
Polystyrene	1599	905	922	-2
Polyvinyl chloride	1550	872	883	-1

SYNTHETIC RUBBER

	1985	1986	1985	% change
	1158	677	679	0

^a Millions of cubic meters. ^b Petroleum-based product only. Source: Ministry of International Trade & Industry



CANADA

Despite slowing economic growth, earnings are up impressively for several of Canada's major chemical producers

Earl V. Anderson, C&EN New York

Next year, the Canadian economy will move slowly, but surely, into its fifth consecutive year of recovery. That alone should be comforting to Canada's chemical companies. But as events of 1986 have proved very clearly, economic growth alone does not afford them the luxury of complacency.

One major reason for this, of course, is that, with a population of only 27 million people, Canada's domestic market is small. And Canadian chemical companies' world-scale plants depend heavily on export markets where, for many products, competition remains strong and prices remain weak. For several Canadian chemical companies, ammonia and methanol are but two such products they would just as soon forget.

As a result, domestic economic growth alone does not guarantee higher chemical earnings. The Canadian economy, as measured by gross national product, probably will increase about 3% this year, according to most estimates. And several Canadian chemical companies have chalked up impressive earnings gains, at least through the first three quarters.

But certainly not all of them. C-I-L is a good example. It is more diversi-

Depressed fertilizer demand clouds chemical operations

fied than most Canadian chemical companies. In the past, this diversification has helped it weather some economic storms better than other major Canadian chemical firms. Not this year, however. Nine-month earnings were down a disappointing 54% despite a 5% rise in sales.

For C-I-L, as for several other Canadian chemical companies, the problem lies primarily in agricultural markets, especially for ammonia. Chemicals used in the mining industry and by the oil and natural gas industries also are hard hit.

C-I-L's agricultural group lost \$7.2 million in the third quarter alone, compared with a \$720,000 profit in the third quarter last year. For the first three quarters, the group lost \$2.2 million, compared with an \$18.7 million profit last year. Behind the drop: lower farm demand and overcapacity that have led to significantly lower ammonia prices.

As a result, C-I-L's agricultural unit is taking steps to "adapt to market realities." One of its ammonia plants is down for maintenance. The company will delay bringing it back on stream until the first quarter of 1987. Demand will be met from inventory. And C-I-L is reducing its staff by offering employees an attractive retirement package.

Other Canadian chemical producers likewise have been hard hit by a depressed agricultural market, both at home and abroad. Although ammonia production is up slightly this year, few if any companies are making money on the product. Meanwhile, output of other agricultural products is slipping. Production of ammonium nitrate will be down about 4% and ammonium phosphate output will be off 5%.

Cominco has shut down its ammonium phosphate plant at Kimberley, B.C., because of worldwide overcapacity and low prices. The

Ethylene, polyethylene outputs score the greatest gains

Thousands of metric tons	Production					% change 1985-86
	1986 ^a	1985	1984	1983	1982	
Ammonia	3760	3620	3493	2885	2509	4%
Ammonium nitrate	1015	1054	969	934	1018	-4
Ammonium phosphate	1240	1301	1383	1259	888	-5
Benzene	660	688	557	580	504	-4
Chlorine	1520	1424	1424	1385	1233	7
Ethylene	1965	1744	1464	1196	1013	13
Hydrochloric acid, 100%	140	158	161	170	135	-11
Phosphoric acid, 100%	590	627	691	656	503	-6
Polyethylene, high density	234	229	227	211	194	3
Polyethylene, low density	870	733	529	412	376	19
Propylene	640	648	665	715	618	-1
Sodium chlorate	365	336	313	294	264	9
Sodium hydroxide	1680	1589	1575	1528	1367	6
Sulfuric acid	3570	3890	4053	3686	3131	-8
Urea	2270	2033	2110	1445	1231	12

^a C&EN estimate. Source: Statistics Canada

company also has shut down—temporarily, at least—its potash operation near Vanscoy, Sask., where inventories were becoming too high.

Despite a soft ammonia market, Canadian capacity is increasing. Ocelot recently completed its 550,000-metric-ton ammonia plant at Kitimat, B.C. Pincher Creek Nitrogen already has brought on stream the first train of its ammonia plant at Pincher Creek, Alta. The Alberta Gas Ethylene-Cominco ammonia plant, with a capacity of 350,000 metric tons a year, will come on stream in the third quarter of 1987.

Methanol is another problem product for Canadian producers. Ocelot lost about \$4.5 million on its petrochemical operations during the first half of 1986 and blames most of the loss on methanol. As a result of poor markets and prices, Alberta Gas Chemical and Celanese Canada, in addition to Ocelot, either have or are cutting back methanol production.

Unlike C-I-L, Celanese Canada is having an excellent year. Through the first nine months, sales were up only 5% but earnings were a hefty 82% higher than last year. Much of the improvement, however, comes from its fiber operations. The company's chemical sales volume is off, primarily because of lower methanol and vinyl acetate exports.

In fact, Canadian chemical exports probably will total about \$3.8

billion this year, down about 4% from 1985.

Meanwhile, Canada's economic growth is pulling in more chemical imports. The estimated \$4.2 billion in imports will be 6% higher than in 1985. As a result, Canada's chemical trade deficit will increase from last year's paltry \$9 million to an uncomfortable \$395 million.

Fluctuating exchange rates can do tricks with trade statistics, however. In Canadian dollars, exports will decline only 1.5% this year, while imports will sport an 8% growth rate.

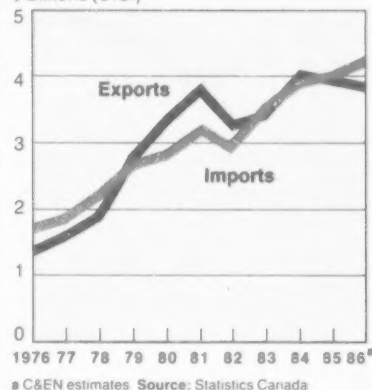
Although first-half figures (the latest available) indicate that exports of plastics and resins are running at about the same level as last year, business is particularly good for some products and producers. At Du Pont Canada, for instance, earnings more than tripled through the first nine months, although sales rose only 6%.

In part, the company credits a strong worldwide demand for polyethylene, which has helped its export sales, and better prices in international markets. Demand for engineering resins also has been strong, both in Canada and in the U.S., which is Canada's major chemical export market.

Du Pont's experience is reflected in this year's production figures for Canadian chemicals. The big gainers, as they have been for the past several years, are low-density poly-

Chemical trade balance slips into red

\$ Billions (U.S.)

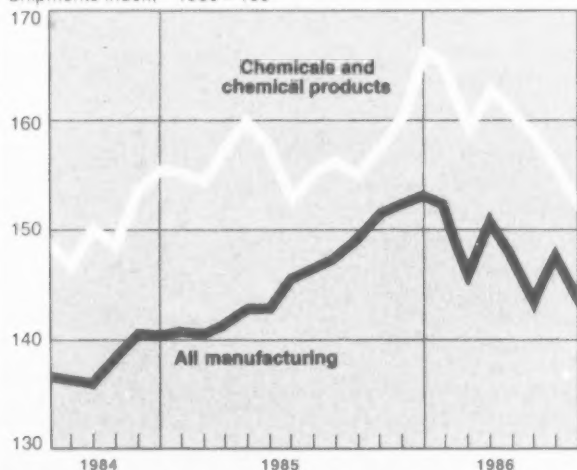


ethylene and its raw material, ethylene. Output of these materials will increase 19% and 13%, respectively. Few other products, with the exception of urea, come close to that kind of increase.

Whether these and other chemical products will be able to turn in better performances next year depends almost as much on the U.S. economy as it does on the Canadian economy. If the economy in the U.S. perks up, Canadian exports likely will improve. Meanwhile, Canadian gross national product will advance between 2 and 2.5% in 1987—not exciting, but not bad either for the fifth year of an economic recovery. □

Chemical shipments have been slipping . . .

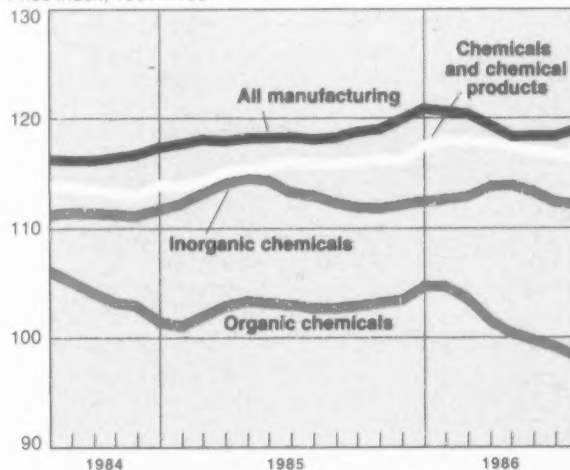
Shipments index,^a 1980 = 100

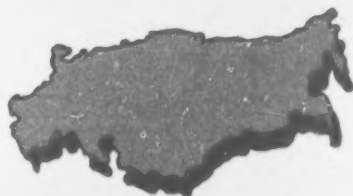


■ Seasonally adjusted. Source: Based on Statistics Canada data

. . . but most prices have held steady

Price index, 1981 = 100





U.S.S.R/ EASTERN EUROPE

**Soviet Union targets
chemical output to rise
nearly one third by 1990
as it plans to emphasize
chemicals in its economy**

Richard J. Seltzer, C&EN Washington

This month, the Soviet Union and its six East European allies in the Council for Mutual Economic Assistance (CMEA)—Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, and Romania—complete the first year of their new five-year plans. Ratified by Communist Party congresses in each country, the plans generally call for more rapid growth in 1986–90 than was achieved or targeted in the previous five years. Although details are not yet defined, the plans give high priority to the chemical industry, as a key industry to spur national industrial and economic development. Indeed, Soviet leaders call for “chemicalization of the national economy.”

The Soviet Union’s 12th five-year plan, for example, targets a 25% increase in industrial output by 1990, a growth of 4.6% a year. The chemical industry is to raise output 30 to 32% by 1990. Moreover, Soviet leaders set the ambitious goal of doubling national income and industrial production by the year 2000, requiring growth of 4.7% a year.

However, numerous major problems continue to beset Soviet industry—as well as the other CMEA economies. Many western specialists doubt the Soviets will meet their five-year and 15-year targets. Indus-

Chemicals gain high priority in industrial development

trial production grew only 3.7% a year between 1981 and 1985 and 4.5% from 1976 to 1980, according to official Soviet statistics. Furthermore, the Central Intelligence Agency estimates that industrial output actually rose just 2% a year in the 1981–85 period and 2.6% from 1976 to 1980—after eliminating upward bias due to hidden inflation and double counting. Soviet industrial growth rates thus continued their long-term decline during the past two decades.

This has been a relatively good year for Soviet and East European economies and industry overall. Growth rates picked up for the U.S.S.R., Poland, East Germany, and Bulgaria, after some slowing in 1985. The two preceding years were also rebound years, following three years of stagnation or even decline. However, results are weaker this year for Czechoslovakia, Hungary, and Romania.

Through September, for instance, Soviet official figures show total industrial output rose 5% compared with the same period last year, surpassing the 4.3% goal for all 1986, and the 4% rise achieved in all 1985. Chemical industry production rose a hefty 8% through September, compared with 5% in all 1985. Fertilizer industry production grew 9%, compared with 7% in all 1985.

Soviet production of several key chemicals is also up this year, but output of others lags. Through September, sodium hydroxide output was up 7%, versus a 3% rise in all 1985. Increases of 7% were also registered through September for sulfuric acid, synthetic fibers and yarns, and plastics. Last year, sulfuric acid output grew less than 3%, fibers and yarns dropped 0.5%, and plastics rose less than 4%.

On the other hand, through nine months this year, Soviet production

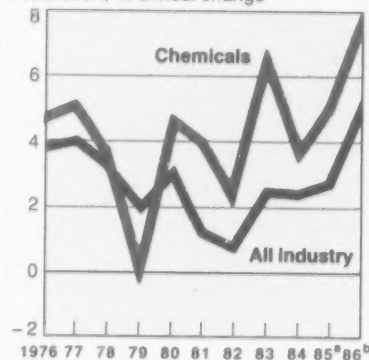
of mineral fertilizers rose just 5%, down from almost 8% in all 1985. And pesticide output dropped 5%, after 3% growth last year.

Meanwhile, Poland’s industrial production for the first half of 1986 was up 5%, well above the year’s target of 3.4%. Last year, its growth slowed to 4% after rebounding to 6% in 1983 and 5% in 1984 from the malaise of earlier years (decreases of 11% in 1981 and 2% in 1982, for example).

Output of the Polish chemical industry rose almost 8%, through June. This compares with growth of less than 3% for all last year, far short of the 1985 target of 8%, and rates of more than 8% in 1983 and almost 6% in 1984. Poland raised output of some key chemicals in the first half of 1986. Nitrogen fertilizer was up 31%, after declining 8% in all 1985. Phosphate fertilizer rose 7% (versus 2% in all 1985). Production also increased for detergents (up 27%) and pharmaceuticals (up more

Soviet chemical growth surpasses industry in general

Production, % annual change



Note: All figures except for 1986 are based on Central Intelligence Agency estimates, which are lower than official Soviet statistics because of postulated upward bias in Soviet figures. ^a Preliminary. ^b For first nine months. Sources: Central Intelligence Agency; Wharton Econometric Forecasting Associates, based on official Soviet figures.

than 12%). However, output of man-made fibers was up only 0.5%, plastics rose just 0.6%, and synthetic rubber production dropped 7%.

East Germany aims for higher growth than any other CMEA state, and it seeks to become Eastern Europe's high-technology leader and supplier, notes a recent report published by Wharton Econometric Forecasting Associates. The East Germans stress technological modernization of their industry, increased labor productivity, cost reduction, and development of domestic energy resources. Their new five-year plan calls for industrial output to grow 8.4% a year.

East Germany's midyear results are in accord with its ambitious plans: Industrial output rose 9%. Aiding this rise was an increase of 9% in industrial labor productivity.

As in the U.S.S.R., East Germany gives top priority to its chemical industry: Its target this year is 9.3% growth, a rate exceeded only by the critical electrical engineering and electronics, and the machine tools and process machinery sectors. Chemical production grew almost 10% through June, maintaining the growth rates of between 9 and 11% achieved during the past four years. Nitrogen fertilizers were up more than 22% at midyear, low-density polyethylene up almost 8%, and polyurethanes up 10%.

Bulgaria is recovering from a rough year in 1985: Industrial production rose less than 4%, well short of the 5.2% target. Through June this year, industrial output is up 6% (the goal for all 1986 is 4.5%). However, as a Wharton report points out, official figures have questionable credibility.

The highest growth at midyear was achieved by Bulgaria's top-priority machine-building sector (12%) and by its chemical industry (8%). Output of plastics, synthetic resins, and adhesives was up almost 15% and paints and varnishes 10%. However, fertilizer output fell sharply, with nitrogen fertilizer down almost 26% and phosphate fertilizer down 19%.

Czechoslovakia, Hungary, and Romania are not meeting growth targets this year. Czech chemical and oil refining output rose just 1%

Soviet chemical output up, but much of East Europe's lags

Thousands of metric tons, 1985	U.S.S.R.	Bulgaria	Czechoslovakia	East Germany	Hungary	Poland	Romania
Mineral fertilizers ^a	33,200	na	1200	4842	na	2270	3096
Change from 1984	8%	na	5.6%	2%	na	-4%	1%
Nitrogen (N)	14,500	836	582	1078	603	1254	na
Change from 1984	9%	0%	1%	12%	3%	-8%	na
Phosphate (P ₂ O ₅)	8,200 ^b	172	353 ^b	299 ^b	130	889	na
Change from 1984	7%	-18%	3%	-3%	-19%	2%	na
Potassium (K ₂ O)	10,500	—	na	3465	na	127	na
Change from 1984	7%	—	na	0%	na	8%	na
Sulfuric acid, 100%	26,000	820	1298	882	520	2863	1900
Change from 1984	3%	-10%	5%	0%	-5%	3%	-1%
Ammonia ^c	19,100	na	na	1210	na	na	na
Change from 1984	8%	na	na	0%	na	na	na
Plastics	5,000 ^d	na	1100	1044	na	586	628
Change from 1984	4%	na	6%	-1%	na	-1%	-4%
Sodium hydroxide	3,056	157	330	667	194 ^e	384	na
Change from 1984	3%	-8%	1%	-4%	0%	1%	na
Synthetic rubber	2,005 ^f	26	70	140	—	126	155
Change from 1984	3%	0%	-1%	-8%	—	6%	-1%

a Nutrient content basis. b Includes ground phosphate rock for direct application and phosphate animal feeds. c Nitrogen content. d Includes resins for man-made fibers. e Includes regenerated NaOH. f Estimated by Central Intelligence Agency. na = not available. Sources: Central Intelligence Agency; East European Statistics Service; Foreign Broadcast Information Service; C&EN estimates, based on official national statistics.

through June, down from almost 4% in all 1985 and well short of the 3% goal for 1986. Hungary's poor results in 1985 continue this year. Industrial production rose just 1% through August. Chemical output dropped 1%, mainly because of a fall in oil products and fertilizers.

By all accounts, Romania's economic statistics are sui generis. Data are largely unavailable, and much of what is released—often claiming record-breaking results—is highly inflated. Still, western analysts conclude that Romania had a very bad year in 1985, and continues to lag in 1986. Chemical output barely grew at all last year, by official figures (the target was 15.7%). Plastics production declined 4%, and sulfuric acid and synthetic rubber output were down almost 1% each.

However, analysts note, for 1986 Romania has again set overambitious goals, at levels that have "lost touch with reality." Industrial output is to grow 9% (versus 5% achieved last year, by official figures). Output of chemicals, the main priority sector along with machine building, is to rise more than 8%.

What are the future prospects for CMEA nations? Their five-year plans all emphasize "intensive" rather than "extensive" develop-

ment—raising output through higher productivity and more efficient management of resources, rather than by greater inputs of fuel, raw materials, capital investment, or labor. Existing enterprises are to be modernized, rather than new ones built. The quality of goods and services is to be raised. And controlled reform will be introduced into the economic system, allowing greater decision making by enterprises and a greater role for market forces, such as prices, wages and other incentives, and profits.

Accelerating introduction of advanced science and technology is the key to the strategy—machine-building and engineering, robotics, electronics, fine chemicals, advanced materials, biotechnology, and other high-technology areas. Science is to be the major source of productivity growth and of increased competitiveness of products in western markets.

However, CMEA nations will not abolish central planning or carry out fundamental structural reforms, which would endanger the authority of current officials. But many western observers consider basic structural reforms essential for any solution to the Soviet bloc's economic problems. □



**Chemical officials
hope freer competition
will boost efficiency,
even make Mexico a net
exporter of chemicals**

Earl V. Anderson, C&EN New York

Next year could be pivotal for the Mexican chemical industry. How it performs in 1987 may well dictate whether the industry will grow the way it hopes to—indeed, the way it expects to—or whether it will continue to be mired in problems that have plagued it for the past several years.

Certainly, Mexico's continuing economic crisis will help color the

Government loosens restrictions on Mexico's petrochemical industry

outcome. However, the government has given the petrochemical industry some impressive tools to work with. It has reclassified many primary (basic) and secondary petrochemicals. Now, some primary petrochemicals, formerly reserved solely for production by Petróleos Mexicanos (Pemex), the state-owned oil company, can be produced by private companies in the secondary petrochemical sector.

The government also has made it possible for these same private companies to import their raw material requirements directly. Previously, only Pemex could import basic petrochemicals to supplement its own output. It then resold the imports to its private-company customers.

Now that Mexico has joined the General Agreement on Tariffs & Trade (GATT), Mexican chemical leaders believe that a fresh breeze of freer international competition will force chemical companies there to become more efficient. And a recently issued report sets some impressive long-term goals for the industry and outlines a strategy to achieve those goals.

The report, significantly a joint government-industry effort, establishes petrochemicals as a priority industry in Mexico. It stresses the need to achieve better harmony among Pemex, the private petrochemical sector, and the ultimate end user. That harmony is conspicuously absent right now. And the report outlines the steps to be taken to make Mexico's petrochemical industry a major net exporter.

That's an ambitious goal but one that Mexican chemical leaders feel can be achieved. In fact, many of them are irked because Mexico, with its enviable hydrocarbon resources, continually runs a chemical trade deficit. Last year's deficit of

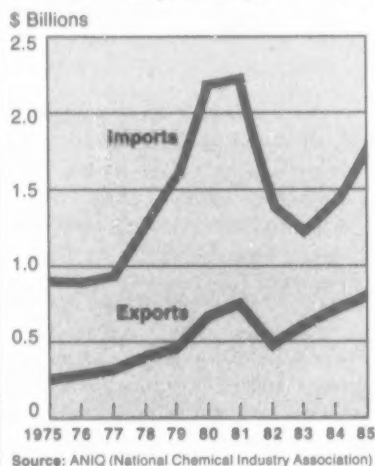
\$968 million was the highest since 1981.

Significantly, most of the increase last year was caused by trade in basic petrochemicals. Exports of these products declined 41%, and imports rose 24% to a record \$681 million. As a result, Mexico's deficit in basic petrochemicals jumped 50% to \$605 million, almost twice the deficit for all other chemicals.

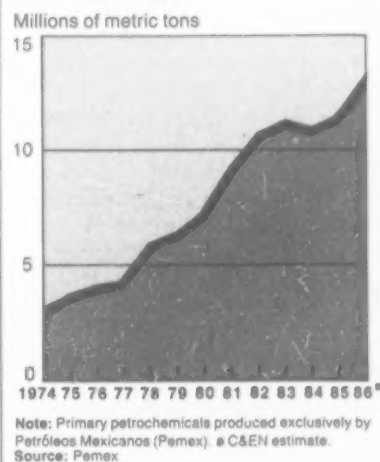
It's obvious that it is in petrochemicals that Mexico's major chemical headaches lie. If this basic petrochemical dilemma can be solved, the rest of the chemical industry will fall into place.

Pemex's petrochemical investment program is expected to help. It will spend \$2.5 billion over the next six years to put an additional 3.7 million metric tons of capacity on stream. Some new units will be operating next year. But Pemex's major project is a petrochemical complex at Morelos. These units will be starting up between 1988 and 1991. □

Chemical trade deficit widens despite export rise



Basic petrochemical output hits new high



DECEMBER 22, 1986

CHEMICAL & ENGINEERING

NEWS

Better understanding of
methyl isocyanate toxicity emerges
Page 17

Capital Spending

Doldrums to continue in 1987 Page 9

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News of the Week

■ The U.S. chemical economy will continue to experience modest growth in 1987, according to economic forecasts. **Page 4**

■ American Institute of Chemical Engineers urges federal, state, and local agencies to coordinate policy on protection of groundwater. **Page 5**

■ Jury decides Monsanto must pay \$108 million to the family of a former employee who died of leukemia in 1980. **Page 5**

■ Successful genetic engineering of cotton plants through the use of recombinant DNA technology is achieved by Agracetus. **Page 5**

■ New chemical process eliminates oxides of nitrogen from engine exhaust gases. **Page 6**

■ Fermenta faces crisis as audit disclosures of major financial irregularities lead to removal of its president. **Page 6**

Letters **2**

Concentrates

Business **7**

Government **14**

Science/Technology **16**

The Departments

ACS Comment **28**

ACS Focus **31**

ACS News **32**

Newscrips **44**

Business

Work-force reductions in the chemical industry continue as a result of streamlining of operations and changing corporate priorities. **Page 11**

Fuel ethanol producers are optimistic about future despite problems such as MTBE contamination of gasoline used in blends. **Page 13**

Government

More research on environmental impact of waste sites is needed to fill gaps in technical knowledge. **Page 15**

Science

Data on the molecular toxicology of methyl isocyanate are not always in agreement, especially on the question of whether MIC enters the bloodstream through the lungs and affects other organs. **Page 17**

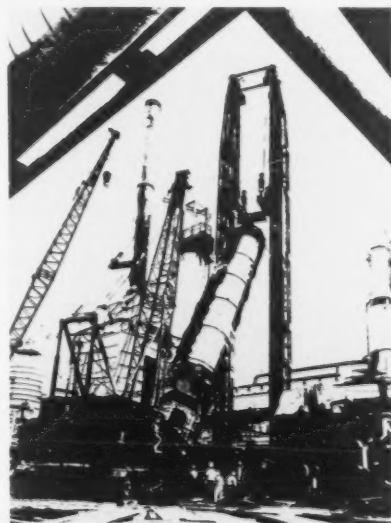
Technology

A new method of treating hazardous liquid wastes—pyrolysis with a thermal plasma field—awaits operating permits. **Page 20**

Industrial & Engineering Chemistry Research consolidates three I&EC quarterlies into monthly issue to speed up publication of papers. **Page 21**

Books

"Biotechnology in Society" is a collection of essays on the science and the social policy issues surrounding it. **Page 25**



Cover Story

Chemical capital spending will see little gain in 1987 because of the slow growth in demand and the decline in crude oil prices. **Page 9**

Chemical Capital Spending To Gain Less Than 1% in 1987

Low capacity utilization by major U.S. chemical firms will continue to hold expenditures on new plant and equipment in check

William J. Storck, C&EN New York

Capital expenditures by U.S. industry will not see any great gains next year, according to economists, as flat domestic demand and only slowly rising exports will continue to hold down the need for new plant and equipment. They point out that spending probably will decline this year, largely because of cutbacks by oil companies brought about by the decline in crude oil prices, and thus revenues. And they caution that, although 1987 may see something of a rebound, this may well be a moderate comeback because of continuing problems in the petroleum and also agricultural areas.

In fact, according to Charles B. Reeder, head of Charles Reeder Associates and former chief economist at Du Pont, the decline in oil prices and its subsequent drag on the economy may have more than offset any increase in consumer spending in 1986, thus causing a slower growth in the economy than if oil prices had maintained levels in effect at the beginning of the year.

This may have important implications for the U.S. chemical industry. A slowing of growth in the economy is usually reflected in the highly cyclical chemical industry. Thus next year probably will see continued slow growth. For an industry that already is seeing average capacity utilization at about 80% of theoretical nameplate, according to government figures, this adds up

to a continued disincentive to invest in, at least, new plants, and probably plant additions, especially for commodity chemicals, as well.

This may well be compounded by forecast slowdowns in two of the chemical industry's big markets—housing and automobiles—and continuing troubles in the agricultural industry. Economists and tax experts are saying that the housing boom is nearing an end partly because of the elimination of many incentives to build in the new tax law and partly because the industry has caught up with demand and there is some softness in the housing market in many parts of the country.

The auto industry will suffer some of the same ills as the housing sector. The tax law, in doing away with deductions for state sales taxes and interest on consumer loans, has moved some planned 1987 auto sales back into 1986, as has cut-rate financing offered earlier this year by the major car makers. Analysts say that these factors undoubtedly will

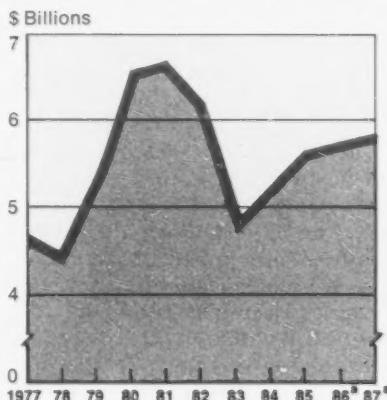
cut into 1987 domestic car production, especially in the first half.

And, few economists see improvement in the farm economy next year, which has been buffeted by high yields, poor demand, and, like much of the rest of the economy, increased foreign competition.

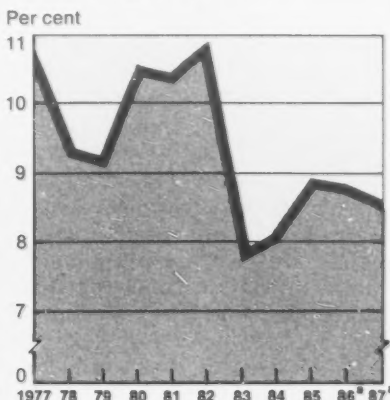
This all means that generally the chief factor that has affected the chemical industry since the last recession—slow demand growth—will continue. And this slow growth in demand once again will hold chemical capital spending low in relation to what it has been in the past. A survey of 12 leading chemical producers by C&EN shows a less than 1% growth in capital spending forecast for next year. This follows an increase of less than 2% in 1986 from last year. The results are based on 11 of the 12 companies. Du Pont, the largest chemical capital spender, had not responded by press time.

Therefore, next year again will see firms spending more on process improvements and plant streamlining than on brand new plants, a

Chemical capital spending remains below 1981 peak ...



... and still lags as a percentage of sales



Note: Combined data from 12 major chemical producers. * C&EN estimate.

Chemical capital spending will be flat in 1987

\$ Millions	1987		1986		Worldwide					Change from previous year	
	Total	U.S.	Total	U.S.	1986 planned ^a	1985	1984	1983	1982	1987	1986
Air Products	\$ 400	\$ 268	\$ 385	\$ 270	\$ 402	\$ 392	\$ 263	\$ 246	\$ 347	3.9%	-1.8%
American Cyanamid	265	212	265	212	200	203	200	165	171	0.0	30.5
Dow Chemical	980	560	920	552	900	806	781	630	829	6.5	14.1
Du Pont ^b	na	na	na	na	1205	1515	1369	1138	1463	na	na
Ethyl	145	138	125	119	135	90	103	85	92	16.0	38.9
W. R. Grace	300	213	244	177	390	348	380	353	560	23.0	-29.9
Hercules	200	170	250	213	215	234	218	168	174	-20.0	6.8
Monsanto	520	468	460	414	525	645	614	560	673	13.0	-28.7
Olin	140	133	135	128	110	154	165	123	139	3.7	-12.3
PPG Industries	400	na	540	na	410	452	315	450	452	-25.9	19.5
Rohm & Haas	200	125	170	110	200	159	134	72	126	17.6	6.9
Union Carbide	525	394	550	385	670	649 ^c	670	761	1179	-4.6	10.0 ^c
TOTAL	\$4075	\$2681	\$4044	\$2580	\$5362	\$5647	\$5212	\$4751	\$6204		
ANNUAL CHANGE^d	0.8%	3.9%	1.5%	-0.5%		8.3%	9.7%	-23.4%	-7.4%		

a Earliest estimates. b Excludes Conoco. c On a continuing business basis. 1985 capital spending was \$500 million. Percentage change for 1986 is calculated using this figure. d Cumulative change for companies reporting. na = not available.

trend that has been prevalent in the chemical industry throughout the 1980s and one that has led many companies to spend more on R&D than on capacity expansion in the past few years.

The 1.5% increase in capital spending estimated by 11 companies in 1986 reflects the real world. At the beginning of this year, companies were predicting that capital spending would rise 2.3%, itself a modest increase and one that probably could not even keep pace with construction inflation. The even more modest 1.5% rise undoubtedly means that real capital spending in 1986 declined, a situation that will continue next year with its 0.8% forecast increase.

Despite the industry trend, some companies increased capital spending strongly in 1986. For instance, such spending at Ethyl Corp. rose almost 39% from 1985 to \$125 million. And American Cyanamid's rose 31% to \$265 million. At an analysts meeting in Philadelphia earlier this month, Cyanamid chairman George J. Sella Jr. said that much of the increase was for construction of manufacturing facilities for new products, particularly the company's new herbicides, and for new and expanded research laboratories for its medical and agricultural businesses. In spite of the increase, however, Cyanamid's capital spending

this year will lag R&D spending, which is estimated at \$280 million.

PPG Industries also raised capital spending significantly this year—almost 20% to \$540 million. And capital expenditures at Dow Chemical are up about 14% this year to \$920 million.

Other chemical firms with increased capital spending this year are Union Carbide, up 10% to \$550 million; Rohm & Haas, up almost 7% to \$170 million; and Hercules, up almost 7% to \$250 million. In Carbide's case, the increase is on a "continuing business" basis. In other words, if the company, in 1985, had been made up of only those businesses that it has in 1986, capital spending last year would have been \$500 million, instead of the \$649 million reported in the 1985 annual report.

The increases at these firms were almost completely offset by declines at four other chemical producers. The largest of these declines was at W. R. Grace, whose estimated capital spending this year fell almost 30% to \$244 million. It must be pointed out, however, that Grace has divested itself of a number of businesses, and so capital spending naturally would be down from the year before. Another firm that spent dramatically less this year was Monsanto, with a 29% drop to \$460 million. Smaller declines were record-

ed for Olin, down about 12% to \$135 million, and Air Products, down almost 2% to \$385 million. Unlike the other companies, Air Products is figured on a fiscal-year basis with the year ending Sept. 30.

For next year, the 11 chemical companies are forecasting a combined increase in capital spending of just 0.8% over this year's spending. And although most of the companies are forecasting increased spending, the few that are not offset the rise. Grace forecasts the largest increase—23% to \$300 million—followed by Rohm & Haas, up almost 18% to \$200 million; Ethyl, up 16% to \$145 million; Monsanto, up 13% to \$520 million; Dow, up 7% to \$980 million; Air Products, up 4% to \$400 million; and Olin, up 4% to \$140 million. Cyanamid, which had such a strong increase in 1986, says it will keep capital spending flat next year at \$265 million.

Capital spending decreases are planned at PPG, down almost 26% to \$400 million; Hercules, down 20% to \$200 million; and Carbide, down nearly 5% to \$525 million.

These companies' capital spending in the U.S. next year will outperform worldwide capital spending. The 10 companies that estimate U.S. capital spending will see it increase an average of almost 4% in 1987. This follows a decline of 0.5% in 1986. □

JANUARY 5, 1987

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CHEMICAL & ENGINEERING

NEWS

Chemicals used in winemaking
Page 19
PRELIMINARY PROGRAM
ACS spring meeting in Denver Page 35

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**Mary L.
Good**
ACS President
Page 2



News of the Week

■ R&D expenditures in U.S. will rise 7.4% in 1987, according to Battelle Columbus Laboratories' annual R&D forecast. **Page 6**

■ Job market for new college graduates in 1987 remains flat, except for graduates with degrees in chemical engineering or chemistry where demand is up. **Page 7**

■ Chemical Abstracts Service donates its entire backfile of *Chemical Abstracts* issues and Collective Indexes to Los Angeles Public Library, a victim of two arson-related fires. **Page 7**

■ Councilors in Region V select candidates for upcoming election to fill vacancy created by the death of director Robert C. Brasted. **Page 7**

Business

Vinyl chloride, styrene, and toluene diisocyanate plants operate near capacity as demand surge takes producers by surprise. **Page 9**

Government

Low risks concept is used increasingly in regulating cancer-causing chemicals; however, concept is rejected by libel court system. **Page 14**

Technology

Johnson Wax, a major producer of specialty chemicals and still a privately held firm, celebrates 100 years of existence. **Page 16**

Science

Synthesis of gene that encodes the heme protein cytochrome b_5 aids study of cytochrome's characteristics. **Page 17**

Link between cancer and thyroid hormones receptor is found by two groups of researchers. **Page 18**

Updated data on academic science/engineering are now available from NSF's division of science resources studies. **Page 18**

Preliminary Program

Highlights of 193rd ACS National Meeting to be held in Denver in April include division symposia, advance registration coupon. **Page 35**

Cover: Photo by Greg Pease

President's Message	2
Letters	4
Editor's Page	5
Concentrates	
Business	8
Government	13
Science/Technology	15
The Departments	
ACS Comment	29
ACS News	31
Newsclips	64



Special Report

Chemical additives used in the production, storage, and shipping of wines are an integral part of winemaking. **Page 19**

R&D FUNDING OUTLOOK:

Battelle forecasts 7.4% rise in 1987

Research and development expenditures in the U.S. will amount to about \$127.4 billion in 1987, Battelle Columbus Laboratories says in its annual R&D forecast. That figure represents an increase of 7.4% over the \$118.6 billion the National Science Foundation estimates was actually spent for R&D in 1986.

According to Battelle economists Jules J. Duga and W. Halder Fisher, who prepared the forecast, part of the increase will be absorbed by inflation, which they estimate at 3% (for R&D) in 1987. Thus the real

increase in R&D expenditures would be about 4.3%, slightly higher than the 4.26% average annual growth rate over the past 10 years.

Of the \$127.4 billion, industry is expected to furnish \$63.8 billion (50% of the total, and a 7.2% rise from 1986). The federal government will provide \$59.5 billion (46.7% of the total, up 7.6% from last year). The remainder will come from academic institutions (\$2.75 billion, or 2.2% of the total) and other nonprofit organizations (\$1.45 billion, 1.1% of the total).

During the past decade, the annual compounded rate of real growth in R&D support has averaged 5.3% for industry and 3.3% for the federal government. Duga and Fisher point out that the growth in industrial funding has been a recent trend; until 1979, the federal government supported more R&D than did industry.

Four government agencies—Department of Defense, Department of Health & Human Services, Department of Energy, and National Aeronautics & Space Administration—will account for 92.7% of total federal R&D spending in 1987. This amount is about the same as the 91.5% for the four agencies in 1986. The forecast notes, however, that the allocations among the four will change significantly in 1987.

DOD will fund about 70% of the federal total, compared with 65% in 1986. Most of the increase in R&D will involve acquisition of major weapons systems.

DOE will fund 7.6% of the total, down from 9.5% in 1986. The cut will mainly affect energy supply and conservation programs; defense-related efforts and general science programs won't be hurt very much.

The loss of the Challenger shuttle and the resulting investigations

have affected NASA's entire operation, including the orientation of research programs and associated budgets, the forecast says. Although NASA R&D support will increase slightly in 1987, it will represent a smaller share of the federal total—6.3% vs. 6.5% in 1986.

There also will be "significant cuts" in support of the biological and health science areas, and a "continuing de-emphasis on research in the 'soft' sciences," according to the forecast. For example, the HHS share of the federal total will be only 8.9%, compared with 10.3% in 1986.

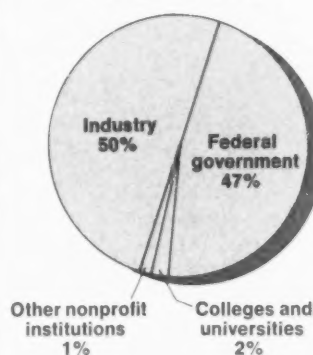
Regardless of the source of funds, private industry will, as usual, do most of the work. For 1987, "performance" by industry will account for nearly \$94 billion, or 73.5% of the total. Of the rest, \$14.7 billion (11.5%) will be done in-house by the federal government, \$15.5 billion (12.2%) by colleges and universities, and almost \$3.6 billion (2.8%) by other nonprofit organizations.

Among the industries, the aerospace industry will keep its usual lead, with performance of about \$23.6 billion in total R&D. Of that amount, almost 75% will be federally supported. The electrical machinery and communication industry will come in a close second, with total R&D performance of almost \$21.3 billion. But federal support will represent only 34.6% of the total. About \$10.8 billion will be spent on R&D for "chemicals." Of that amount, 97.1% will be funded by industry, only 2.9% by the federal government.

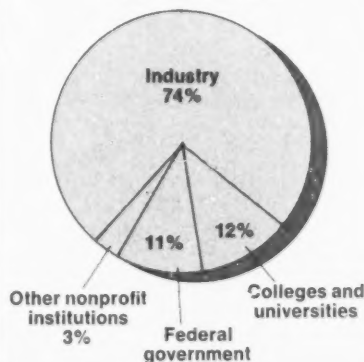
Although industrial R&D support has been growing, shifts in patterns seem to be emerging. In particular, the Battelle economists warn, the recent increases in mergers, acquisitions, and "restructuring efforts" may have a significant impact on industry R&D expenditures. □

R&D funding to reach \$127.4 billion in 1987

Source of funds



Performers of R&D



Demand Surge Surprises Plastics Intermediates Producers

With plants operating near capacity, vinyl chloride, styrene, and toluene diisocyanate face growing tightness in supply

Bruce F. Greek, C&EN Houston

Demand for three major plastics intermediates—vinyl chloride, styrene, and toluene diisocyanate (TDI)—rose far more in 1986 than producers and marketers had expected. Although some improvement over a small demand slump in 1985 was forecast, production gains of more than 5% were not anticipated. To meet demand for these intermediates, producers ran their plants at practical capacity through much of the year, occasionally going above effective capacity, but also being hit with unplanned shutdowns of equipment due to a variety of mechanical problems.

Improved U.S. demand and strong export demand have spurred output. The increased exports were particularly useful to producers in gaining higher prices late last year after declines earlier had accompanied falling crude oil prices. Domestic demand was strengthened by a combination of economic factors—moderate growth in consumption of products made from these intermediates and inventory rebuilding that resulted from lower interest rates and prospects of higher sales volumes.

Reports of tight supplies became widespread during the fourth quarter of 1986 as it became clear that the strong demand earlier in the year would not decline significantly. Slightly improved profitability and apparent tight supplies led to

talk of capacity expansions. Except for debottlenecking programs that are more extensive than usual, few expansions to make these intermediates are planned. Consequently, tightness of supply could continue for one to two years, depending on how cycles in the general economy influence demand.

The immediate future will reflect the higher demand growth and relatively stable capacity situation.

Key Chemicals

Prices likely will remain firm as long as a recession is avoided. Imports will rise and exports will fall, causing the net of exports over imports of the plastics intermediates to fall more rapidly than they otherwise would.

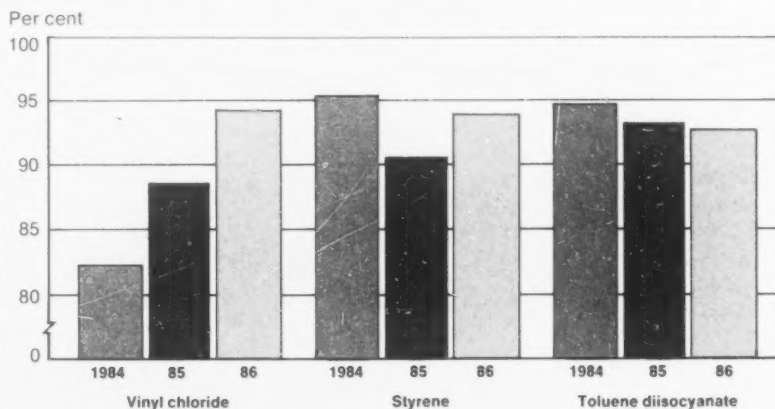
The foreign trade in these plastics intermediates remains a source of supply for domestic uses. In 1986, exports of each of the plastics intermediates accounted for more than

10% of their U.S. production. For TDI, it was close to 25% of production. Exports have been under pressure because of higher prices, but prices have been partially offset by the decline in value of the dollar in some importing countries where the currency is pegged to the U.S. dollar. Similarly, imports have been rising, from small bases, however, because of firming prices in the U.S. long-term export commitments.

Competition to U.S. exports of vinyl chloride has been growing as the result of completion of new capacity in Saudi Arabia. Production from the new capacity is expected to be either polymerized on site or exported to polymerization plants in Far Eastern countries whose polyvinyl chloride requirements have been rising rapidly. In addition, plant expansions in other parts of the world where these intermediates are made could put a downward pressure on U.S. exports.

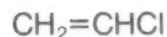
For details of the near-term outlook for these plastics intermediates, see the following pages.

Operating rates for plastics intermediates continue high



Sources: International Trade Commission, C&EN estimates

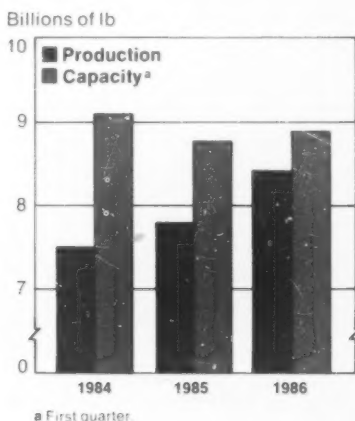
Key Chemicals



Vinyl chloride

- **Demand well up**
- **Capacity steady**
- **Prices raised**

PRODUCTION/CAPACITY



MAJOR PRODUCERS

Borden Chemical, Dow Chemical, Formosa Plastics, Georgia-Gulf, B. F. Goodrich, PPG Industries, Shell Chemical, Vista Chemical

HOW MADE

Dehydrochlorination of ethylene dichloride made by reacting chlorine or HCl with ethylene

MAJOR DERIVATIVES

Vinyl polymers almost 100%

MAJOR END USES

Fabricated plastic items almost 100%

FOREIGN TRADE

Exports—rising to 1.5 billion lb,
Imports—rising to 200 million lb

PRICE

16 to 17 cents per lb

Vinyl chloride production set a surprising pace last year. The record output would be even higher if more plant capacity had been available. Despite high production, strong domestic and export demands have caused tight supplies. Prices have risen about 10%, but additional hikes are expected in 1987.

Fourth-quarter 1986 production of vinyl chloride was forecast at slightly more than 2 billion lb. If the forecast holds, the 1986 total output will exceed 8.4 billion lb, up more than 600 million lb from the 1985 volume of 7.8 billion lb, an increase of nearly 8%. Output also showed unexpected strength in 1985, rising from 7.5 billion lb produced in 1984 in what had been forecast as a weak year for vinyl chloride.

Output in 1986 did not follow historical patterns and rose more than had been forecast. First-quarter production, at slightly more than 2 billion lb, met many forecasts based on the strong showing in late 1985. That was in line with historical production records that call for a strong first quarter to meet demand for polyvinyl chloride pipe resins needed for pipe going into the spring and summer surge of housing and commercial construction.

Second-quarter vinyl chloride production last year exceeded the first quarter by a small amount, which is not always the case but is not unprecedented. The relatively high output in that quarter was attributed to pipe demand's holding up because housing remained strong.

The third quarter traditionally has been the weakest quarter for vinyl chloride. But in 1986, output rose almost 11% over the second quarter, reaching 2.285 billion lb, according to preliminary estimates of the U.S. International Trade Commission. It is more usual for third-quarter production to decline 5 to 10% from the first and second quarters.

For the three quarters, vinyl chloride output totaled 6.38 billion lb, according to ITC preliminary estimates. With fourth-quarter production of 2 bil-

lion lb, the forecast total for the year of 8.4 billion lb will be met. Industry sources believe, however, that fourth-quarter output was more than 2 billion lb, and possibly 2.1 billion to 2.2 billion lb, which would lift the 1986 total to 8.5 billion to 8.6 billion lb. It is likely that the first quarter of 1987 will have about the same production rate.

The increased and unprecedented production rates for vinyl chloride last year hinted at continued tight supply. As 1986 began, capacity to make vinyl chloride was 8.8 billion to 8.9 billion lb. Minor debottlenecking during the year raised capacity a small amount but probably not enough to offset lost production due to unexpected plant outages during the year. At a maximum total production of 8.6 billion lb and operable nameplate capacity of 8.8 billion lb, average operating rate would work out close to 98%. A more conservative estimate would be 94%, based on 8.4 billion lb of production and 8.9 billion lb of capacity.

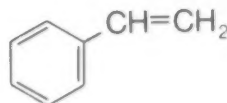
The apparent tightness in supply stems partially from export demand growth, the same outlet that might provide additional volume for U.S. consumers of vinyl chloride should producers choose to reduce exports in favor of U.S. sales. Exports in 1986 were forecast to reach 1.5 billion lb, or nearly 18% of production. Imports, also rising, offset exports about 200 million lb for a net of 1.3 billion lb, or 15% of production.

Vinyl chloride selling prices have risen about 10% from midyear 1986, as the production surge continued into the third quarter. More price increases are forecast for 1987. Currently, export prices are about the same as domestic prices for vinyl chloride, indicative of the supply situation. Profitability, however, has not improved very much because both ethylene and chlorine prices increased last fall. Nevertheless, future increases in vinyl chloride prices could stay ahead of raw material costs and finally relieve the low profitability for producers.

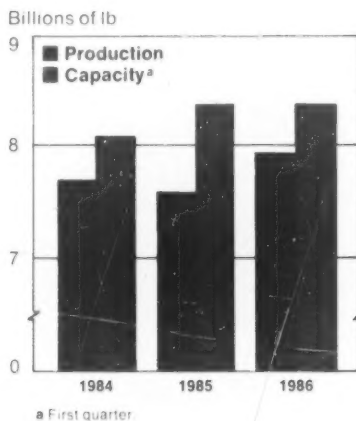
Key Chemicals

Styrene

- Demand stronger
- Capacity on hold
- Prices raised



PRODUCTION/CAPACITY



MAJOR PRODUCERS

Huntsman Chemical, Amoco Chemical, Arco Chemical, Cos-Mar, Chevron Chemical, Dow Chemical, Sterling Chemicals

HOW MADE

Dehydrogenation of ethylbenzene; coproduced with propylene oxide

MAJOR DERIVATIVES

Polystyrenes 65%, styrene-butadiene elastomers and latices 15%, acrylonitrile-butadiene-styrene polymers 10%

MAJOR END USES

Fabricated plastic and rubber products almost 100%

FOREIGN TRADE

Exports—holding at about 1.3 billion lb, imports—rising to about 250 million lb

PRICE

25 cents per lb

Strong demand for styrene is expected to continue during the early part of this year. In last year's second half, polystyrene demand proved to be stronger than expected, spurring its production. Consequently, supply has tightened, and producers are considering capacity expansions. Prices have firmed, allowing much of the price increases of feedstock benzene to be passed on.

Styrene output hit a record in 1986 of close to 7.9 billion lb. Polystyrene manufacture accounted for most of the production increase, with other uses logging lackluster performances. Estimated 1986 output was well above the 7.7 billion lb produced in 1984 and is a 5% increase over 1985 production of 7.5 billion lb.

When 1986 began, nameplate capacity for styrene was nearly 8.4 billion lb, providing sufficient supply to meet a modest demand growth of 2 to 3% expected for what generally is considered to be a mature product. At that time, no significant capacity expansions were imminent because of the long history of overcapacity for styrene. But now producers are shifting their attention to the tight supply situation.

As 1986 progressed, output was reduced by an unusual number of plant problems. Several of these production problems occurred at a time when some plants temporarily were down for routine maintenance. Thus about 10 days' production was lost by styrene plants during 1986. That loss reduced capacity for the year by about 200 million to 250 million lb, or about 3%.

With a 1986 capacity of 8.4 billion lb, and a projected output of 7.9 billion lb, the average operating rate was close to 94%, a very high level for styrene. A 3% capacity outage for the year would raise the operating rate to close to 97% of nameplate capacity, supporting current reports of tight supply. Additional maintenance shutdowns are scheduled for early 1987.

Price increases have resulted from

the current tight supply of styrene as recently as December and have led to rumors of further increases should benzene prices move above the mid-90s cents-per-gal level of last month. After the cut of 3- to 4-cent temporary voluntary allowances from the list prices of 28 to 29 cents per lb, most styrene sells for about 25 cents per lb, a price up nearly half from six months ago.

Exports of styrene in 1986, estimated to be near the 1985 level of 1.3 billion lb, probably declined slightly from 1985. Imports of styrene, although still relatively small, likely rose to 250 million lb, up about 25% over 1985. Higher prices will continue to lower net exports.

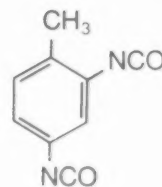
The major use of styrene—various straight and rubber-modified polymers—accounts for nearly 65% of its U.S. consumption. Growth of about 350 million lb in polystyrene's use of styrene was expected last year, easily covering the increase in styrene production. Large end uses of polystyrene, such as packaging and disposable items, are growing faster and provide much of the total gain.

Polymers of styrene and butadiene rank a distant second in uses of styrene. Demand for styrene-butadiene latices, used heavily as carpet backings, is growing slowly, aided by strong sales of carpet. Production of styrene-butadiene elastomers, used mainly in tires, fell last year because tire production continued to decline under pressure from the marketing of longer-life tires and from rising tire imports. Outlook for these polymers in styrene end uses is for little or no growth, interspersed with periods of decline.

Other polymers—acrylonitrile-butadiene-styrene resins, unsaturated polyester resins, and a host of miscellaneous resins—take relatively small volumes of styrene. Some of the resins, such as the styrenic thermoplastic elastomers, are growing well, but from a small base. Hence, compared with polystyrene, their effect on styrene demand remains negligible.

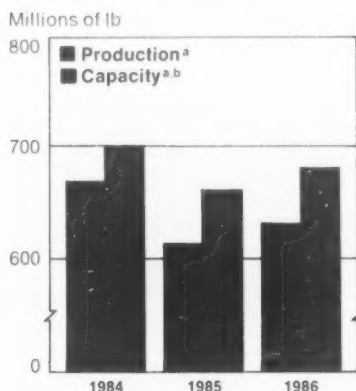
Key Chemicals

Toluene diisocyanate



- **Demand up a bit**
- **Capacity to rise**
- **Price firmer**

PRODUCTION/CAPACITY



a 80/20 mixture of 2,4- and 2,6-toluene diisocyanate.
b First quarter.

MAJOR PRODUCERS

BASF Wyandotte, Dow Chemical, Mobay, Olin, Rubicon Chemicals

HOW MADE

Nitration of toluene, reduction to diamine, reaction with phosgene, and purification with recovery of coproduct HCl

MAJOR DERIVATIVES

Polyurethane almost 100%

MAJOR END USES

Polyurethane foams (mostly flexible) 85%, coatings 5%, elastomers 5%

FOREIGN TRADE

Exports—holding at about 150 million lb, imports—negligible

PRICE

\$1.00 per lb

In a year of generally modest business growth, 1986 production of toluene diisocyanate (TDI) followed suit and also apparently grew modestly. After a slow start early in the year, demand for this ingredient of polyurethane foams improved. Prices rose somewhat and plants operated at near optimum levels. Concerns over toxicity at both producing and consuming (foam manufacturing) plants apparently have eased. Investments in better facilities and improved operating techniques have led to reduced toxicity problems and may lead to greater output.

Capacity to make TDI expanded modestly in 1985 and 1986, and what expansion took place came mainly through debottlenecking programs of the several producers. TDI capacity may rise further this year. The additions brought nameplate capacity to about 690 million lb as 1987 began.

If demand growth fits recent patterns, the capacity expansions likely will almost equal the increases in demand expected during 1987. After a notable decline in output in 1985, production growth in 1986 was expected to be about 2 to 3%, or 10 million to 20 million lb, bringing total output to 630 million to 640 million lb of TDI. Consequently, the operating rates for both years ran about 94% of estimated nameplate capacity—typical of the rates for TDI plants in recent years.

Last year producers experienced a few plant operating problems that reduced output, but enough spare capacity was available to handle the small growth by both domestic and export demands during the year. Earlier in 1986, when some production was lost, export demand was stronger, and domestic demand weaker. Consequently, a supply crunch was averted. Exports of TDI last year are estimated to have held at about 150 million lb, or nearly a quarter of production, up slightly from 1985 exports. Longer term, it is expected that exports will remain near the same level.

Most U.S. consumption of TDI (large-

ly an 80/20 mixture of the 2,4- and 2,6-isomers) goes into flexible urethane foams. About 5% of consumption goes into urethane coatings, and less than 5% goes into urethane elastomers. Hence, consumption of TDI depends mainly on demand for flexible foam, the largest market for which continues to be furniture. (Bedding is considered separately.) Currently, furniture demand is strong and is expected to hold.

The next largest market for flexible foams is transportation, mostly in automotive seating. Demand last year could approximate levels of the late 1970s because output of autos held up. Unit consumption of foams, however, has declined with the downsizing of autos. Some threat to TDI consumption continues to come from *p,p'*-methylene diphenyldiisocyanate (MDI). Because molders believe that faster production is possible by using MDI and that the seat quality is better, use of TDI is slowly being replaced by MDI.

Carpet underlay (padding) ranks third in use of flexible urethane foams, and, with estimates of year-to-year variations in consumption ranging up to 50%, it appears to cycle far more than other uses. The variations in both commercial and residential carpet demands influence the cycles and upset forecasts for this use of TDI.

Bedding—largely either all-foam mattresses or topper pads for interspring mattresses—ranks fourth as a use of flexible foam. Growth in the bedding market for foams has been slow during the 1980s and is expected to remain so.

Other uses of TDI in urethane coatings, elastomers, and miscellaneous uses (mostly adhesives and sealants) are small and are growing at diverse rates. Some of these products have excellent performance characteristics, but have high costs of application or fabrication. None affected demand for TDI last year very much, nor is any expected to have much effect during this year.

Industry Restructuring Is Still Hitting Older Chemists Hard

Michael Heylin, C&EN Washington

More details of the major industrial manpower cuts that are continuing to afflict the chemical profession are available in the latest report by the American Chemical Society's Committee on Professional Relations (CPR) on such mass terminations (CPR) on such mass terminations. The report covers the investigation of seven multiple terminations that occurred between July 1985 and July 1986 and cost the jobs of as many as 400 chemists and chemical engineers.

All seven of the terminations involved older chemists with 10 or more years of service. This confirms the continuing vulnerability of experienced chemical professionals to the corporate restructurings that have pervaded the chemical and related industries in recent years. On a brighter note, the latest report indicates that those fired are tending to get somewhat better separation terms, including more generous severance pay.

By far the largest of the terminations was in Harvey, Ill., where Atlantic Richfield closed its technical center. According to terminnee reports, more than 300 jobs were lost, including many chemical professionals. Other major terminations were at PPG Industries, where about 50 chemical professionals were involuntarily separated from facilities in Lake Charles, La., and New Martinsville, W.Va., and at Betz Laboratories, where as many as 40 chemists lost their jobs in Trevose, Pa. The other terminations involved 33 chemists and chemical engineers from Henkel, 25 from Ayerst, 17 from Uniroyal, and 12 from Koppers.

The report also states that nine other mass terminations have been confirmed and are currently being

Employer compliance with ACS guidelines

These employers provided information		Approximate number of terminees	Advance notice	Severance pay	Assistance	Pension vesting	Employee service	Protection plans	Retiree privileges
American Home Products, Ayerst Laboratories (Princeton, N.J., and Rouses Point, N.Y.)		25							
Henkel (Minneapolis, Minn., and Burlington, Iowa)		33							
Koppers (Monroeville, Pa.)		12							
Uniroyal (Middleburg and Naugatuck, Conn.)		17							

These employers provided no information; hence, all ratings based on terminnee responses

Atlantic Richfield, Arco Petroleum Products (Harvey, Ill.)		250							
Betz Laboratories (Trevose, Pa.)		40				*			
PPG Industries (Lake Charles, La., and New Martinsville, W.Va.)		50							

* No information from any source.

□ Employer met or exceeded guideline standard.

▨ Two or more individuals below guideline standard.

■ Employer was substantially below guideline standard, which is defined as follows:

- Advance notice—less than two weeks.
- Assistance—no assistance rendered.
- Severance pay—less than one week per year of service.
- Employee service—more than 40% of terminnees had 10 or more years of service.
- Protection plans—no continuation of protection plans.

investigated by CPR. These involve Chesebrough-Pond's, Exxon Research & Development Laboratories, Farmland Industries, GTE Laboratories, International Minerals & Chemical, Los Alamos National Laboratory, Rorer Group, Sandoz, and Syntex Chemicals.

A mass termination is defined by CPR as a situation in which the employment of three or more chemists or chemical engineers is terminated by a single employer within

a six-month period for reasons other than continuing evidence of previously documented inadequate performance, completion of a contract, or cause. Terminations do not have to all occur at one location.

This new CPR report is the latest in a series of 24 produced by the committee since 1974. They compare the performance of employees having multiple terminations with seven standards contained in ACS's Professional Employment Guide-

lines. The seven firms investigated in this new report complied with these standards an average of 42% of the time. This compares closely with an average of 43% for the just over 200 terminations investigated in the previous 23 reports.

These reports are based on data provided by both employers and terminees. On average about two thirds of employers provide such data. For the latest report, four of the seven did so. The data from terminees are usually gathered with the aid of ACS local sections. CPR received help from the Louisiana, Pittsburgh, Princeton, Chicago, and Western Connecticut sections in preparing the latest report. CPR also asks individual members to send information on terminations. This should be addressed to: Office of Professional Relations, 1155—16th St., N.W., Washington, D.C. 20036. This office will provide, on request, copies of all CPR termination reports as well as a summary list of multiple terminations that have occurred within the past 10 years.

In addition to the length of ser-

vice of terminees and severance pay, the seven standards used in these reports are concerned with pension vesting, assistance in finding new employment, employee protection plans, advance notice, and rehire privileges.

For the latest report, CPR has formalized the criteria by which it determines if an employer has complied with, violated, or "substantially" violated each standard. An employer is deemed to be in compliance if it meets a standard on average and not more than one terminations reports treatment below the standard. A violation occurs when two or more individuals report substandard treatment, even if, on average, the standard is met. A violation is deemed "substantial" when a standard is not met on average, even if some individuals report treatment at or above the standard.

The database that the committee has to work with in making such determinations varies widely. The major challenge is identifying terminees. Once identified, terminees are apparently reasonably willing to supply information. However, those responding ranged from a high of 92% of total terminees to a low of 2%. This lowest response was for the big Atlantic Richfield shutdown at Harvey.

The guidelines state that employees with a minimum of 10 years' service should not be terminated, except for inadequate performance or cause. But all seven terminations in the latest report involved such seasoned employees. In four cases, more than 40% of those terminated had 10 or more years of service.

This performance continues the recent trend. All but five (or 9%) of the 54 terminations investigated by CPR in its six reports since 1984 involved chemical professionals with 10 or more years of service. For the previous 18 reports, compliance with this standard averaged 29%.

CPR points out that its latest report shows "the 1985-86 trend in multiple terminations toward the use of involuntary early retirement and the termination of long-term employees as operations are closed permanently." In addition, it says,

"Earlier industrial experience, with short-term shutdowns intended to ride out temporary business down cycles, resulted in a different pattern, one in which those terminated were the newest employees who could reasonably expect to be recalled to employment in the future."

In the latest report, four of the seven employers met or exceeded the standard that calls for severance pay of two weeks' pay per year of service. For the first 18 reports, this standard was complied with by only 15% of employers. For the last six reports, this percentage moved up to 28%. And for the last four reports, it was 32%.

Of the other five standards, the one calling for full pension vesting after 10 years has been complied with in 84% of the terminations examined in all 24 CPR reports. In the latest report it was complied with in all six cases for which data were available.

In the latest report all but one employer met the standard for outplacement assistance for terminees. Compliance with this standard has slightly improved in recent years and now stands at 69% for all terminations investigated.

Long-term compliance with the standard calling for extension of employee protection plans beyond the date of termination is 50%. However, in the latest report, only one employer, Ayerst, met this standard. The other six provided such protection for the severance period, but not for the recommended month beyond that.

In the latest report, three employers gave the recommended four weeks of advance notice. The other four did not do so on a consistent basis. For instance, at Henkel the average notice was more than 14 weeks. But some terminees claimed they received as little as one week. Compliance with this standard averages 38% for all 24 CPR reports.

The standard for rehire privileges simply states that such privileges should be carefully explained to terminees. Apparently this is rarely done to the satisfaction of CPR. None of the seven employers covered by the latest report did so. For all 24 reports, only one employer of seven has met this standard. □

ACS guidelines

Advance notice. Four-week minimum.

Severance pay. Minimum is two weeks per year of service. Additional notice may be given, by mutual agreement, in lieu of severance pay.

Assistance. Efforts should be made to place terminations in another position within the organization, or terminations should be given assistance to find employment elsewhere.

Pension plan vesting. Full vesting after 10 years' service.

Employee service. Those with minimum of 10 years' service should not be terminated except for continued evidence of previously documented inadequate performance or cause.

Employee protection plans. Should be extended for a minimum of one month, plus two weeks for each year of employee service, following termination at same rate of contribution as before. Employee would have additional 31-day grace period.

Rehire privileges. Rehire privileges should be carefully explained to terminees.

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JANUARY 12, 1987

CHEMICAL & ENGINEERING

NEWS

Congressional Outlook '87

Page 7

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News of the Week

■ Federal budget proposal calls for higher funding levels for NSF, NASA, and Department of Energy's defense R&D program, but funding cuts for NIH and DOE's energy R&D. **Page 4**

■ President Reagan seeks sizable increase in funds for Strategic Defense Initiative, although survey of NAS members shows few believe it a feasible enterprise. **Page 5**

■ Construction of 12-story ACS office building is halted by D.C. government officials after monitoring equipment indicated possible wall movement in adjacent historic church. **Page 5**

■ Chemist Yuri Tarnopolsky will be allowed to leave the U.S.S.R. within the next few weeks, the latest dissident whose case has been resolved in the past year. **Page 6**

■ Nuclear safety research program is in need of reform, according to recent evaluation of the Nuclear Regulatory Commission. **Page 6**

Business

Poly(ethylene terephthalate) bottle resins supply will rise more than one third this year, allowing for more growth in consumption. **Page 15**

Science

New bimetallic 38-atom Au-Ag cluster, one of largest metallic clusters ever to be made and structurally characterized, may provide insights to the synthesis and structure of higher-nuclearity clusters. **Page 21**

Dietary fat intake is not linked to breast cancer, according to a Harvard medical school study of 90,000 women. **Page 22**

Innovative chemistry exhibit, to be completed in 1988 at the California Museum of Science & Industry, will offer visitors hands-on demonstrations of chemical processes. **Page 23**

Technology

Two hazardous material databases now available in microcomputer version will give emergency response personnel equipped with portable computers immediate access to information. **Page 23**

Cover: Photo by C&EN's David J. Hanson

Letters **2**

Concentrates

Business **13**

Government **19**

Science/Technology **20**

The Departments

ACS Comment **24**

Meetings **25**

Newsclips **48**



News Focus

The 100th Congress, now firmly controlled by the Democrats, likely will have numerous confrontations with President Reagan over environmental issues, chemical weapons, and international trade. **Page 7**

Supplies of PET Bottle Resins To Stay Tight for Next Few Years

Producers of poly(ethylene terephthalate) resins for bottle use will boost capacity more than a third this year; demand could rise even faster

Bruce F. Greek, C&EN Houston

Supplies of poly(ethylene terephthalate) (PET) resins that are used for making bottles will be more plentiful this year than in the past two years. Capacity to make these resins will rise more than one third by the end of 1987. The additional resin supplies could lead to more replacement of glass and metal in containers.

Demand has been rising at more than 10% annually for the past few years and could rise faster now that output will be raised. The result is that no permanent end to the tight supply situation of 1985-86 can be expected this decade. However, expansions now being planned could lift U.S. capacity another 33% before 1990.

These PET resins, often called solid stated because of conversion to a more crystalline form, have a higher molecular weight than PET resins used in fibers. Solid stating is a second step in manufacture, a further polymerization following initial production of PET. In addition to being used to make bottles, solid stated PET resins also are made into films, trays, and other items.

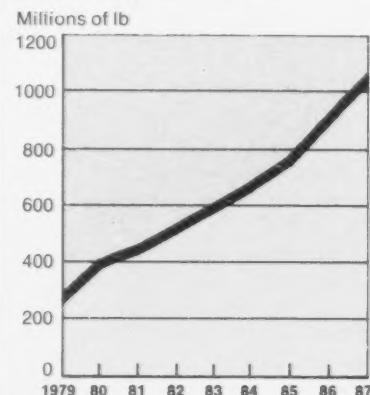
The increase in demand for PET bottle resins has exceeded the growth in total demand for PET resins. The bottle or solid stated resins, PET film resins (with similar molecular weights), and engineering PET resins account for about a third of total PET production. The other two

thirds goes into polyester fibers, mainly for apparel manufacture and tire cord. Total PET production was about 5 billion lb in 1986. Less than 20%, or an estimated 925 million lb, was solid stated resins used for bottles. PET film resins production probably reached 650 million lb, and engineering resins accounted for another 100 million to 125 million lb of PET. Over recent years, demand for these nonfiber resins has grown at high rates, while fiber demand has stabilized in the range of 3.3 billion to 3.4 billion lb per year.

Current capacity to produce PET resins exceeds 6 billion lb in the U.S., possibly close to 6.5 billion lb. After fiber requirements are met, ample capacity remains to meet the rising demand for the nonfiber resins. The supply crunch stems from limits in capacity to convert the resins for use in bottles, films, and molded engineered components.

Plants making resins for nonfiber uses increase the molecular weight and thereby increase the intrinsic viscosity, orient films by stretching, and compound resins by adding fillers and reinforcing materials. As plant capacity to make the various kinds of nonfiber-grade resins is

Output of PET bottle resins keeps rising steadily



Source: C&EN estimates

added, the basic PET capacity will be available to supply these plants used for the further processing. If, as a result of rising imports of apparel containing polyester fibers, U.S. polyester fiber production declines in the future, then some additional basic PET polymerization capacity could be shifted to making the nonfiber resins in the additional plants.

During 1986, capacity to make sol-

PET bottle resins at a glance

How produced: From poly(ethylene glycol terephthalate) similar to fiber-grade PET (relatively low molecular weight polymer and lower intrinsic viscosity) by further polymerization during which by-product ethylene glycol is removed using hot nitrogen gas and intrinsic viscosity rises from about 0.5 to range of 0.7 to 0.8

Producers: American Hoechst, Eastman Chemical Products, Goodyear Tire & Rubber, ICI Americas

Capacity: Estimated at slightly more than 1 billion lb per year at beginning of 1987

Production: Exceeded 900 million lb in 1986; estimated 1.05 billion lb in 1987

Foreign trade: Exports continue to increase and could total 150 million lb in 1987

Price: 50 to 70 cents per lb, depending on grade

id stated PET resins for bottles and other containers, as well as miscellaneous items, totaled about 950 million lb. With 1986 production estimates at 925 million lb, that capacity was run at more than 97% of its total. If allowances are made for maintenance, changes in grade, and mechanical problems, this operating rate is more than full out.

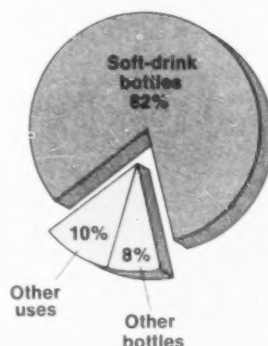
As 1987 begins, an additional 125 million lb of capacity has become available. Eastman Chemical Products just completed startup of an expansion at its Columbia, S.C., plant. Eastman will start up another expansion of the same size during the second quarter. If no problems develop at these new plants, Eastman alone will increase U.S. capacity nearly 200 million lb. About midyear, Goodyear plans to start up the first of three 100 million lb increments of capacity addition.

By the beginning of 1988, capacity in the U.S. will be close to 1.3 billion lb, and possibly higher, if other producers add unannounced capacity through debottlenecking. During 1988, Eastman is scheduled to add 220 million lb and Goodyear 100 million lb of capacity to bring capacity in two years to more than 1.7 billion lb per year. Other producers, such as American Hoechst and ICI Americas, also could add to their capacities, sending the total even higher by 1989.

The capacity expansions for solid stated PET will come on stream just in time this year to ease the tight supply situation. Most of the output from additions will be used in meeting the expected increase in demand of 125 million lb or more. Output in 1987 will top 1 billion lb for the first time and possibly will reach as much as 1.1 billion lb, if some of the current test programs for containers and trays prove PET bottle resins to be the most attractive material.

PET bottle producers are moving to gain more of many other markets. Following their success in introducing 2-L soft-drink bottles, they have taken most of the large-size bottle market from glass. In 1987, the half-liter, or 16-oz, single-service bottle is expected to be the container providing a big share of the growth in solid stated resins. Near-

Soft-drink bottles dominate PET bottle resin market



Note: C&EN estimates based on forecast U.S. consumption of 800 million lb in 1986.

ly 70 million lb more resin will be needed to make some 1.2 billion additional 16-oz bottles this year, to meet a forecast total of 3 billion bottles this year. About 25 g of resin are used in each bottle.

The outstanding advantages of PET resin for soft-drink bottles are in lower cost, lighter weight, and their shatter-proof property. Disadvantages are shorter shelf life of carbonated beverages caused by carbon dioxide leakage. The cost savings in use of PET resins decline as bottle size declines, even with efforts to reduce the amount of resins per unit. For example, as much as twice as much resin is required for four half-liter bottles as is required for one 2-L bottle.

Metal cans, mostly aluminum, continue to be strong competitors of PET resins for smaller-size containers. Despite improvements in bottle-molding machines that allow faster production rates and thinner walls, and improvements in filling machines that allow faster rates, the competition from cans (and to some extent glass) could restrain the shift toward PET resins.

All other bottles, often called custom bottles, account for a much smaller share of PET bottle resin consumption. Alcoholic beverage bottles apparently have a large potential for PET. So far, a variety of problems have limited such use, however. For example, wine bottles often need barrier coatings to provide greater resistance to oxygen penetration and thus increase shelf

life. Liquor bottles have had a mixed reception. The miniature size has conquered the airline industry because of its weight. Larger sizes of liquor bottles are widely available, but reduced liquor consumption nationwide and resistance to plastic bottles by consumers and distillers have prevented the anticipated growth. Beer bottles offer a huge potential market because of the weight and handling advantages. The big drawback to the beer market remains a lack of a hot fill property to allow pasteurization. Barriers to oxygen penetration also continue to be a drawback in making the PET bottle competitive with glass bottles or cans.

Food, cosmetics, toiletries, and pharmaceuticals increasingly have been packaged in containers of PET bottle resins or modifications of the bottle resins. Foods that can be put into containers at relatively low temperatures are going more and more into PET resin bottles and containers, which often are custom-designed. The newer crystallizable PET bottle resins represent a large market potential for use in trays for meals that can be heated in either conventional or microwave ovens, frequently replacing aluminum trays. Currently, the whole area of non-bottle uses of PET bottle resins is only 10 to 15% of the size of the soft-drink bottle market, but it could become a fast growing use as additional resin becomes available.

PET bottles can't be refilled in the U.S. because the temperatures needed for cleaning and sterilizing cause distortion in the bottle. Recycling PET bottles provides a use for the resin, although costs often can't be justified. In the future, however, the volume of resin involved will make recycling more attractive. Recycled PET bottle resins can be used in such products as fiberfill for insulating sleeping bags, jackets, and bedding; unsaturated polyester for glass fiber-reinforced fabricated items; polyols for urethane foam products; thermoformable sheet; industrial coatings; and other smaller-volume products, including decomposition back to the monomers. Recycling thus may eventually become an additional advantage to the use of PET bottle resins. □

CALENDAR OF EVENTS
Scientific meetings
Page 58

JANUARY 10, 1987

- A1250-1

1/21/87

CHEMICAL & ENGINEERING

NEWS

R&D Funding

Chemical firms plan
slight rise this year
Page 11

Federal budget proposes
8% increase in 1988
Page 21

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News of the Week

■ **NAS panel gives mixed review for U.S. export controls related to national security.** Page 6

■ **Newly patented heavy crude oil and water emulsion will be marketed as fuel oil.** Page 7

■ **Chemical stocks have been rising to record levels since Jan. 2, slightly outperforming the Dow Jones Industrial Average.** Page 7

■ **In Bhopal case, Union Carbide wins same evidence-gathering rights as India.** Page 7

■ **Leading U.S. experts on cocaine addiction pinpoint priorities for future research and summarize current knowledge.** Page 8

■ **Defense Secretary Weinberger's annual report to Congress calls for continuation of underground nuclear testing.** Page 8

Cover: Biotechnologist monitors distributed digital control system for advanced fermentation processes at Smith Kline & French Laboratories' R&D facility in Upper Merion, Pa.

Letters 4
Editor's Page 5

Concentrates

Business 9
Government 19
Science/Technology 30

The Departments

New Products 31
ACS Comment 52
ACS News 54
People 65
Newsprints 78

Business

Chemical industry R&D spending is projected to rise moderately in 1987, but at a slower rate than last year. Page 11

International Business

Lonza, the chemicals arm of Swiss aluminum company Alusuisse, is stepping up its efforts to become an international company. Page 13

Science

Multiple quantum NMR has been adapted to "count" number of atoms in a cluster, a previously untapped facet of the technique. Page 35

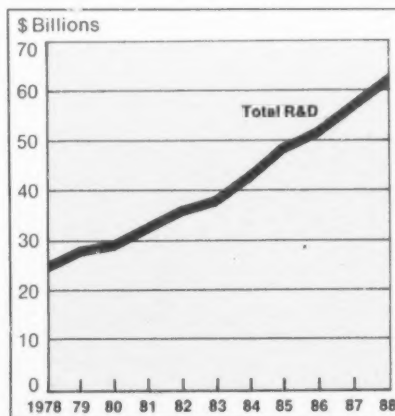
Poisonous gas releases are reported at Lake Nios in Cameroon, where 1746 people were killed last August by a similar eruption. Page 38

Books

Author Christopher Swan foresees an increasingly important role for photovoltaics in nation's energy future. Page 41

Meetings

C&EN's semiannual calendar of meetings and events lists those of interest to chemists and chemical engineers. Page 58



Government

Administration requests 8% increase in federal R&D budget for 1988, with a whopping 70% of the budget tagged for the Department of Defense. Page 21

Heavy oil/water emulsion seeks fuel oil market

A new emulsion technology that allows heavy crude oil and refinery by-products to be mixed with water into a low-viscosity, burnable fuel has been developed and patented by Petroferm, a small chemical specialties company located in Fernandina Beach, Fla. It has licensed the technology to Steuart Petroleum, a leading independent marketer of petroleum products in the eastern U.S.

The emulsified product, known as preatomized fuel (PAF), is a particularly stable emulsion of heavy hydrocarbons and about 30% water, explains Petroferm's president William R. Galloway Jr. It has a low viscosity that is not dependent on temperature. The company expects it to compete favorably with No. 6 fuel oil for large industrial and utility applications. Unlike No. 6 fuel oil, PAF can be stored and transported at ambient temperatures. It

also burns more efficiently, Galloway says, "yielding a substantial reduction in particulate emissions compared to No. 6 oil." Its water content lowers its combustion temperature, and that decreases the nitrogen oxides produced during combustion. Sulfur emissions from the emulsified fuel depend on the sulfur content of the original petroleum starting material. PAFs made from starting materials with different sulfur contents can be blended to produce a fuel mixture that can be tailored to meet local sulfur emissions standards, Galloway says.

Petroferm's technology base comes from exploiting natural bacterial systems that produce oil-emulsifying biopolymers and surfactants. The proprietary chemicals it uses to make PAF include biopolymers, biostabilizers, and classical surfactants, the company says. □

Chemical stocks rise with market

As the Dow Jones Industrial Average broke through the 2000 barrier earlier this month and continued rising to record levels almost every day, chemical stocks more than went along for the ride. Since the beginning of the year, they have outpaced the Dow Jones average slightly.

Between Jan. 2, the first trading day of the new year, and Jan. 14, chemical stocks as measured by C&EN's chemical stock index rose 7.2%. The Dow Jones Industrial Average rose just 5.6% to close at 2035.

The C&EN index also outperformed most of the other standard measures of stock market activity.

While the C&EN index rose 7.2%, the New York Stock Exchange Composite index increased 6.8% to close at 151; the Standard & Poor's 500 index climbed 6.6% to close at 263; and the Standard & Poor's 400 Industrials rose 7.0% to close at 294.

Only the indexes of smaller stock activity outperformed the C&EN measure. The American Stock Exchange Index, between Jan. 2 and Jan. 14, rose 8.3% to close at 290. But the best performance was seen in the over-the-counter stocks. The Over-the-Counter Composite rose 10.4% to 390; the Over-the-Counter Industrials rose 12.2% to 397.

The C&EN chemical stock index is made up of the weighted stock prices of seven major chemical companies—American Cyanamid, Celanese, Dow Chemical, W. R. Grace, Hercules, Monsanto, and Union Carbide.

Of the companies that make up the index, Carbide has been the best performer since the first of the year, rising 13% to close at \$25.75 per share on Jan. 14. It was followed by Dow Chemical, rising 8.8% to close at \$65.25 per share, and Monsanto, up 7.6% to close at \$82.75 per share.

The remaining four companies all showed below average increases. Grace increased 6.1%; Hercules rose 5.9%; Cyanamid increased 4.9%; and Celanese rose just 0.2%. □

Carbide wins round in Bhopal court battle

Union Carbide Corp. has won a key point in its legal battle with the Indian government over who is to blame for the chemical disaster in Bhopal. The Second U.S. Court of Appeals in New York ruled last week that Carbide should be given rights of gathering evidence in India equal to those the Indian government enjoys in the U.S.

The ruling was the second of two decisions made by the court. The first was to keep the trial in India, not move it back to the U.S. That decision ends any involvement by American lawyers on behalf of the victims.

In its appeal, Carbide was concerned that Indian procedures of discovery would prevent the company from gathering all the evidence it needs in showing that public and corporate elements in India were responsible for the disaster. India argued that Indian law was sufficient to guarantee Carbide all the rights of discovery it needed.

Carbide was appealing part of the decision made last May by the District Court in New York. The decision, which basically went in Carbide's favor, was that the trial be held in India, since most of the evidence resided there. Because the Indian government was basing its case on faulty engineering design by Car-

Chemical stocks have outperformed most other indexes

	Jan. 14, 1987	Jan. 2, 1987	% change
C&EN Chemical Stock Index	464	433	7.2%
Dow Jones Industrial Average	2035.01	1927.31	5.6
New York Stock Exchange Composite	150.58	141.01	6.8
American Stock Exchange Index	289.68	267.49	8.3
Over-the-Counter Composite	389.95	353.26	10.4
Over-the-Counter Industrials	396.80	353.53	12.2
Standard & Poor's 500	262.64	246.45	6.6
Standard & Poor's 400 Industrials	293.78	274.58	7.0

Note: C&EN index based on the weighted stock price of American Cyanamid, Celanese, Dow Chemical, W. R. Grace, Hercules, Monsanto, and Union Carbide.

Chemical Industry R&D Spending To Rise Moderately in 1987

Major chemical producers project a 4% hike in research expenditures this year, following a 7% increase in 1986

William J. Storck, C&EN New York

The growth of the U.S. chemical industry's research and development spending in 1987 will slow considerably from 1986, according to C&EN's annual survey of 12 large chemical producers. The survey shows that R&D spending for 10 of the companies that were able to estimate their spending by press time will increase only 4% this year after an estimated increase of 7% in 1986. (Union Carbide and PPG Industries could not yet estimate 1986 spending nor could they forecast 1987 expenditures.)

The 4% increase for chemical firms in C&EN's survey is much lower than the 7% increase in R&D spending for all industry forecast by Battelle Columbus Laboratories (C&EN, Jan. 5, page 6).

The chemical industry's modest 4% increase also means that, adjusted for inflation, chemical R&D spending will have been essentially flat since 1985. The constant-dollar increase is figured using Battelle's estimates for R&D inflation for 1987 of about 3%.

The essentially flat nature of constant-dollar R&D spending is not surprising as corporate reductions in employment roles have been focussed on salaried workers and have cut into research roles along with other white collar programs. The paradox, of course, is that firms continue to say they are increasing their emphasis on higher-value-added

products—items that, by their very nature, require greater R&D effort in terms of development as well as technical support for customers.

However, in many cases, this increased dependence on higher-value-added products is often taking place because companies are divesting themselves of their commodity businesses or acquiring companies making specialty products, rather than building the new businesses internally. A good example of this has been Monsanto, which has sold off its styrene and other commodity operations, while purchasing G. D. Searle, thus swinging its emphasis much more quickly than it could have done if it had decided to achieve the switch entirely through in-house R&D.

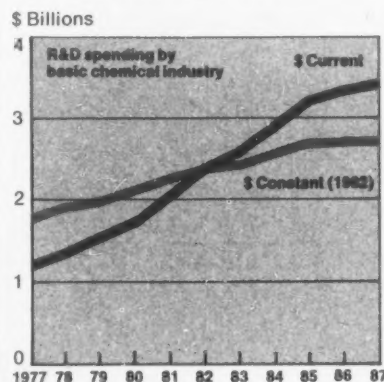
Thus, while the newly acquired operations may take more research dollars than the disposed-of commodity businesses, the increase for the total corporation is not so large as it would have been if the commodity businesses had been retained. This is because some R&D effort went along with them as they

were divested. Further, in some cases, the commodity businesses go when the company decides to build on its existing specialty operations. In these cases, R&D spending actually can go down. During these times of flux in the chemical industry it becomes worthwhile to look at R&D spending as a percentage of sales to determine if a company is maintaining its funding levels, rather than looking only at the raw R&D spending totals.

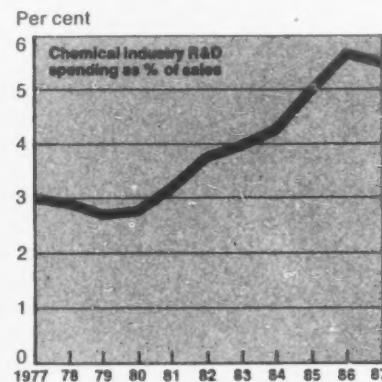
For the companies surveyed, C&EN estimates that R&D spending will amount to about 5.6% of sales in 1986, up from 5.0% in 1985. Although some of that is due to a relatively lackluster sales increase last year, it does indicate that companies are spending a bigger portion of their budgets on R&D.

Chemical companies also are directing a bigger percentage of future-oriented spending (capital expenditures plus R&D expenditures) toward research. In 1986, R&D for the 10 companies responding to the survey averaged almost 46% of total future-oriented spending for the

Growth of R&D spending will slow in 1987 . . .



. . . and will fall as per cent of company sales



Note: For companies listed on page 12. Sources: C&EN surveys and estimates, Battelle Columbus Laboratories

American Cyanamid, W. R. Grace will post biggest gains in R&D spending

\$ Millions	Planned 1987	Actual 1986	Planned 1986	1985	1984	1983	1982	1981	Change from previous year		R&D spending as % of sales	
									1987	1986	1986	1985
Air Products ^a	\$ 59	\$ 61	\$ 60	\$ 51	\$ 44	\$ 40	\$ 37	\$ 32	-3.3%	19.6%	3.1%	2.8%
American Cyanamid	315	280	265	251	232	208	185	166	12.5	11.6	7.3	7.1
Dow Chemical	650	600	600	547	507	492	460	404	8.3	9.7	5.3	4.7
Du Pont ^b	1110	1070	1030	1080	1000	875	775	647	3.7	3.9	6.8	7.2
Ethyl	47	47	47	47	40	39	39	37	0.0	0.0	2.9	3.0
W. R. Grace	110	98	100	92	81	73	64	57	12.2	6.5	1.8	1.8
Hercules	67	73	69	76	72	74	74	65	-8.5	-4.1	2.8	2.9
Monsanto	575	575	520	470	370	290	264	233	0.0	22.3	8.1	7.0
Olin	60	57	59	53	52	49	45	38	5.3	7.5	3.3	3.0
PPG Industries	na	na	176	176	150	127	127	119	na	na	na	4.0
Rohm & Haas	133	130	125	124	109	100	92	77	1.9	4.8	6.1	6.0
Union Carbide	na	na	191	275	265	245	240	207	na	na	na	3.1
TOTAL	\$3125	\$2991	\$3242	\$3242	\$2922	\$2612	\$2402	\$2082			5.6%	5.0%
ANNUAL CHANGE^c	4%	7%		11%	12%	9%	15%	16%				

a For fiscal year ended Sept. 30 b All figures exclude Conoco c For those companies reporting na = not available

group, more than double the 21% posted as recently as 1980. This is partly due to falling capital expenditures because of stagnant to decreasing demand for chemical products, but rising R&D budgets also definitely play a part. For the 10 companies surveyed, capital expenditures fell almost 40% between 1980 and 1986, but at the same time R&D spending was increasing more than 90% for an average of more than 11% per year.

For the 10 companies estimating their R&D expenditures, Du Pont is by far the largest at about \$1.07 billion for 1986 or almost 36% of the total. To make the comparisons consistent, Du Pont's Conoco operations are excluded. The 1986 figure for Du Pont is up about 3.9% from 1985

levels. In 1987, Du Pont forecasts R&D spending of \$1.11 billion, up about 3.7% from 1986.

The biggest increase in 1986 was at Monsanto, where spending rose an estimated 22% to about \$575 million as the company added expanded research programs at its Searle subsidiary. At the beginning of last year it had forecast a solid 11% rise, but the final figure beat that by far. For 1987, however, Monsanto says its R&D spending will remain essentially the same as last year.

Air Products also showed a large increase last year, with R&D spending rising 20% to \$61 million. However for 1987, the R&D budget at Air Products has been trimmed 3.3% to \$59 million as a result of the elimination of some minor non-

strategic areas and cost control steps that the company has taken. However, a spokesman says funding of major programs continues at levels equal to those in 1986.

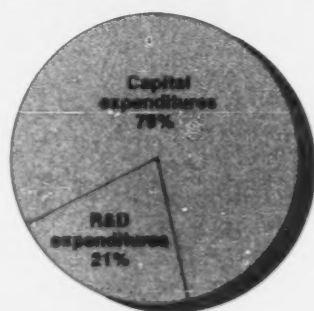
American Cyanamid spent 12% more on R&D in 1986—\$280 million—than it did in 1985. Like Monsanto, it exceeded its earlier estimate, spending about \$15 million more than it had intended at the beginning of last year. For 1987, Cyanamid expects to spend about \$315 million, up 13% from 1986 levels.

Dow Chemical's R&D spending also increased more than average in 1986, with a 9.7% rise from 1985 to \$600 million. For 1987, the company forecasts an almost equal increase of 8.3% to about \$650 million.

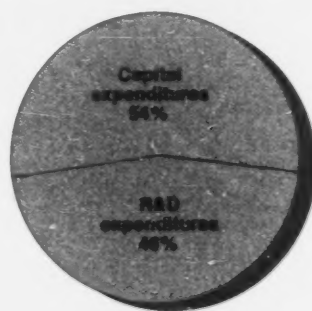
Olin also increased its budget slightly above average in 1986, with a rise of 7.5% to \$57 million. It will increase spending again in 1987 at a rate of 5.3% to \$60 million.

Besides Air Products, the only company to forecast a decrease in R&D spending for this year is Hercules. A company spokesman says that spending in 1987 will total about \$67 million, down 8.5% from 1986. And last year's R&D spending was down 4.1% from 1985. He says, however, that the decline this year will largely come because R&D budgets for water soluble polymers have been switched to the company's joint venture with Henkel in that area. □

R&D spending as per cent of future-oriented expenditures has increased dramatically



Total 1980 = \$8.45 billion



Total 1986 = \$7.42 billion

Note: For companies listed above. Source: C&EN surveys and estimates

Administration Proposes 8% Rise In Federal R&D Budget for 1988

Department of Defense R&D budget consumes 70% of total R&D funding; proposed funding for basic research is up only 4% to \$9.7 billion

Janice R. Long, David J. Hanson, and
Wil Lepkowski, C&EN Washington

"Dead on arrival" was the phrase most often used by political pundits to describe the fiscal 1988 budget proposal that President Reagan sent to Capitol Hill Jan. 5. That phrase has always had a certain validity. No Congress has ever rubber-stamped a President's entire budget proposal, but with the Democrats firmly in control of both branches of Congress this year, it may be truer than ever.

However, it must be noted that when it comes to research funding, President Reagan and Congress have not been that far apart during his six years in office. Both think that science and technology have an important role to play in enhancing national security and strengthening the U.S.'s competitive position in international markets. Thus, although Congress has trimmed some of the Administration's research funding requests, particularly those for the Department of Defense, for the most part the President's R&D budget proposals have served as baselines, which are rarely cut and often increased.

That being the case, 1988 looks like another good year for federal research programs, unless Congress resorts to last-minute, across-the-board cuts to meet the mandatory deficit-reduction target of \$108 billion. The budget, as proposed by Reagan, does meet that target.

In an overall budget that is up only 1% from 1987 to \$1.024 trillion, obligations for R&D are up 8%, or \$4.7 billion, to \$62.4 billion. However, obligations for basic research are up only 4%, or \$400 million, to \$9.7 billion. More than half of that amount goes to support basic research at universities, according to Presidential Science Adviser William R. Graham. He noted that from 1982 to 1988 the amount of federal funds allocated to basic research will have grown more than 50%, despite the relatively low rate of growth in fiscal 1988.

According to Graham, the fiscal 1987 R&D budget proposal exemplifies the Administration's recognition that the country's "future position in global markets will depend to a great extent upon the continuing development of the foundation of our science and technology in basic research; the allocation of our national resources on a long-term and reliable basis to generate new knowledge; and the effective and timely transfer of new knowledge

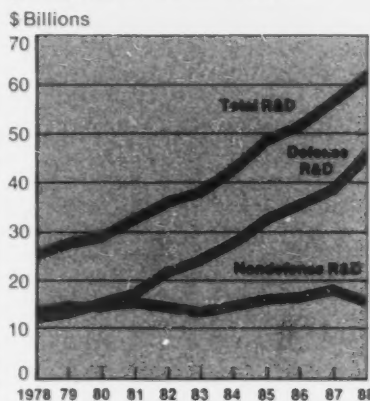
from our laboratories and universities to our industry, economy, and national security." In addition, he says, the budget continues the emphasis of previous years on enhancing national security.

That emphasis just about jumps out of the R&D budget request. Once again the proposed increase in the Department of Defense budget for research, development, testing, and evaluation (RDT&E) is more than the total increase proposed for all federal R&D programs.

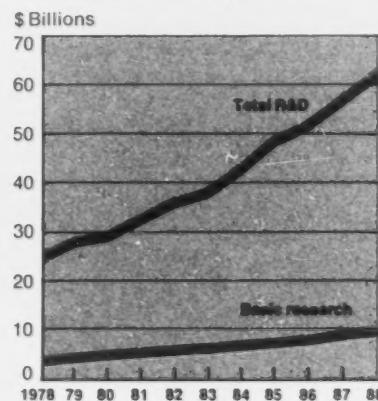
The Department of Defense budget is up 18%, or \$6.8 billion, to \$43.7 billion. Within that total, funding for the Air Force's RDT&E programs is up 21% to \$18.6 billion, the Army's 16% to \$5.5 billion, the Navy's 12% to \$10.5 billion, and the defense agencies' 23% to \$8.8 billion.

According to Defense Secretary Caspar W. Weinberger, "The President's highest priority defense effort is assessment of Strategic Defense Initiative technologies to support possible development decisions planned for the 1990s." The RDT&E

**Defense R&D has risen as
per cent of total R&D . . .**



**. . . while basic research's
share has changed little**



Sources: Office of Management & Budget, Office of Science & Technology Policy

budget request contains a total of \$5.77 billion for SDI work. That's an increase of 61%, or \$2.18 billion, over the fiscal 1987 funding level.

In addition, Weinberger says the RDT&E budget "reflects a balanced support of basic research and exploratory development in areas of emerging, high-potential technologies." However, according to DOD's own figures, funding for what most would consider basic research at DOD is up only 3%, or \$26.3 million, to \$918 million in fiscal 1978. Funding for development work is up 20%, or \$6.8 billion, to \$40.1 billion.

The requested 11%, \$273.8 million, increase to \$2.7 billion for the Department of Energy's defense R&D programs is enough to put its overall R&D budget request in the black. DOE's total R&D budget is up 2%, or \$133 million, to \$5.7 billion. However, the energy R&D budget is down 5%, or \$140 million, to \$2.9 billion.

Despite the overall lower request for energy R&D, some programs are slated for increases. Funding for the clean coal technology program, for instance, would get a 33% rise to just under \$200 million. In fiscal 1988, the program will focus on technologies that could retrofit, repower, or modernize existing coal-burning facilities.

Also on the upswing is the environmental research program, which is up 12%, or \$30 million, to \$288 million. The budget increase will go, in part, to support expanded research programs on the sources and health effects of radon exposure and on detecting changes in human DNA caused by exposure to toxic pollutants. Finally, the budget for the general science programs is up 13%, or \$95 million, to \$815 million. The budget provides substantial increases for R&D on accelerators and experimental facilities, such as the continuous electron beam accelerator.

However, the budget request for supporting research and technical analysis is down 7%, or \$42 million, to \$597 million. That total is reduced because DOE is not seeking continued funding for a number of university construction projects that Congress added to its fiscal 1987

budget. In fact, DOE is asking Congress to rescind, or take back, the \$69 million provided for the projects this year. If the projects aren't funded, the budget request reportedly would allow for a 5 to 6% increase in funding for basic energy sciences, which funds both the chemical sciences and materials sciences research programs.

Facing real budget decreases at DOE are conservation R&D, down 50% to \$80 million; electric energy systems and storage, also down 50% to \$14 million; fossil R&D, down 44% to \$169 million; and solar R&D, down 36% to \$94 million. The Administration has requested these kinds of cuts in these programs in every budget request it has sent to Congress, but Congress has never gone along with them and probably won't in fiscal 1988 either.

The fiscal 1988 budget request for the National Institutes of Health seems to be made up largely of "smoke and mirrors." Documents from the Office of Management & Budget show NIH's budget up a munificent 26%, or \$1.7 billion, to \$8.1 billion in fiscal 1988. Documents from NIH's parent organization, the Department of Health & Human Services, show NIH's budget falling from \$6.2 billion in fiscal 1987 to \$5.5 billion in fiscal 1988, a 10% decrease.

The HHS budget documents do not provide a line item breakdown of the budget by each institute; those details won't become available until late this month, when the budget is normally sent to Capitol Hill, so it's hard to tell what these conflicting figures really mean. However, the discrepancies seem to center on the number of new and competing research project grants NIH will be funding, a matter of ongoing dispute between the Administration, which has tried to decrease the number, and Congress, which keeps increasing it, to 6400 in fiscal 1987 to be exact.

According to HHS, the 1988 request for NIH is \$5.87 billion in obligational authority. But this amount includes \$334 million carried over from its fiscal 1987 appropriations, which have already been approved by Congress. The Administration is in effect requesting a

\$334 million decline in NIH's fiscal 1987 spending. But HHS says that its fiscal 1988 request includes \$2.7 billion in order to meet future year commitments generated by new and competing grants awarded in 1988. In other words, it wants to provide full multiyear funding of those grants up front. The bottom line appears to show that both the 1987 and 1988 budgets are going to be lower than Congress probably wants.

According to HHS, the 1987 appropriations provided a 17% increase in research funding over 1986. "Such a large increase, especially in research project grants, cannot be sustained without significant displacement of other activities." Thus, it says, the proposed 1987 carryover of \$334 million will reduce the number of projects by 700, resulting in only 5700 new and competing projects. The result of all this, however, might be a loss in the number of new grants that might be made for years after 1988. In the effort to budget multiyear support for NIH grants, the impact of lowering the number of grants may be hidden from all but the most searching eyes.

One item receiving special attention in the fiscal 1988 budget request is research on AIDS, acquired immune deficiency syndrome. Nearly \$345 million has been targeted for work in that area, in several institutes, including vaccine development and clinical studies of promising drugs. However, the Administration also is proposing to cut back support of other research areas. It proposes not to fund any more biomedical support formula grants, funded at about \$60 million for fiscal 1987, and it wants to drop \$10 million in extramural construction projects. New construction also would be slowed at NIH, with a proposed construction budget of just \$5 million for fiscal 1988, down from \$32 million this year.

For the Food & Drug Administration, the President has proposed a \$35 million budget increase, quite large considering the tight budgets usually set for regulatory agencies. But most of the increase is to come from \$34 million in new fees FDA is supposed to charge companies for doing product reviews. This action

will require legislation and approval of Congress, and the Administration says such legislation is being prepared.

A third HHS agency developing a significant research budget is the Alcohol, Drug Abuse & Mental Health Administration. The Administration has proposed \$361 million to support about 1600 research projects in fiscal 1988. This is a slight drop from the \$376 million appropriated by Congress for this year. Much of the budget will go to research centers to support basic research in neurosciences, epidemiology, and molecular biology.

The National Aeronautics & Space Administration will never be the same as it was before the Challenger accident. Despite plans to move ahead with space shuttle flights in early 1988, events are moving past the agency at a rapid pace. The Defense Department is developing its own rockets to launch military equipment, and the Administration has begun an initiative encouraging private companies to fund their own rockets for business satellites. Still, the proposed fiscal 1988 budget for NASA shows a significant increase for R&D. On the other hand, NASA programs for space flight are down, primarily because, unlike the fiscal 1987 budget, the new budget includes no funds to build a new space shuttle.

Space station development continues to be a priority at NASA, getting a greater than 80% increase in support to \$767 million. Civilian space efforts will be aided by a \$70 million initiative to expand the technology base in such areas as earth-to-orbit propulsion systems, multi-spectral sensor devices, and high-capacity power systems. Although some programs, such as the Hubble Space Telescope, will be delayed, others are going ahead. NASA says the gamma ray observatory, the Magellan mission to Venus, the Galileo mission to Jupiter, and the Mars Observer will move ahead next year. There is also \$25 million for a long-range project involving a series of spacecraft to study the basic physics of Earth's magnetosphere and solar-terrestrial relationships.

Much of NASA's research efforts will focus on work the agency has

always done, such as wind tunnel testing, computational modeling, and experimental flight tests. Some basic research also will be done on fluid and thermal dynamics, propulsion, materials, and information sciences.

With a budget request of about \$1.9 billion—an almost 17% increase over last year—the National Science Foundation finds itself riding higher than it ever has in its 46-year history. Specific breakdowns won't be forthcoming until Jan. 28, when the Office of Management & Budget releases the detailed budget. But from the Jan. 5 briefing delivered by a "happy" NSF director Erich Bloch, the foundation has won from the Administration the kind of plum it had been seeking for years: commitment by the Administration for significant budget increases over the next five years.

What Congress decides to do with NSF's plans is, of course, another question. But the big news in the fiscal 1988 budget for NSF is that guarantee. Specifically, the Administration is aiming at a \$3.2 billion budget for NSF by 1992, roughly a doubling of the current fiscal 1987 budget and a tripling of the figure for fiscal 1982. Few can contend today that the Administration hasn't been "sold" on science and technology as a policy principle. Indeed, the commitment to double represents one volley in the Administration's set of policies to meet the challenge of international technological competitiveness, according to OMB sources.

On the whole, though, NSF will be carrying out programs little changed basically from those developed over the past two years. There is one exception to that, however. Bloch announced one major new program—establishment of five to 10 new multidisciplinary science and technology centers to join with the existing engineering research centers announced three years ago. The new centers will focus on specific areas in biology and biotechnology, social and behavioral sciences, computer and information sciences, and materials science.

Just how these new centers will differ from the engineering research centers is one of the more interest-

ing questions circulating around NSF. As one division director puts it: "How can you have a science and technology center without engineers, or an engineering research center without scientists?" The concept could give Bloch some organizational challenges. The engineering centers are administered by NSF's engineering directorate whereas the new centers will be funded by the separate research directorates. What could happen is that all center activities could be lumped together in a single NSF unit.

NSF may be riding high, but it is clear from the tone of Bloch's remarks during his briefing that in view of the challenges ahead, the country faces severe problems in its efforts to compete in a technological world. "Too few of our students are choosing science and engineering careers," he says. "Too few of those continue to the Ph.D. And our trade statistics have deteriorated. That is not the way to be competitive."

In any case, NSF is far different than it was five years ago. Science education is back in the saddle with a budget increase of 16%, or \$16 million, to a total of \$115 million. Computer and information science and engineering is a brand new directorate with a \$143 million budget and an increase of 23%. Engineering is still enjoying its revival with a hefty boost—at 26% the biggest of all—to \$205 million. Geosciences rises 16% to \$330 million. The smallest increase goes to the biggest directorate, mathematics and physical sciences, 11% to a total of \$514 million.

Within that directorate is NSF's division of chemistry. And while the breakdown is still pending, sources say that chemistry's growth simply follows the usual historical line—11% for fiscal 1988. Last year the Administration proposed an increase of 18% for chemistry at NSF in response to the Pimentel Report. But Congress scaled that back to 9%. This year NSF isn't so ambitious for chemistry.

Other highlights in the NSF budget include upgraded programs in undergraduate teaching and research, further emphasis on encouraging minorities and women to en-

HOW THE AGENCIES FARE

DOD: development work big gainer

\$ Millions	1988 ^a	1987 ^a	1986 ^a	% change 1987-88
Advanced development	\$14,602.4	\$10,938.0	\$9,472.1	33%
Engineering development	13,112.0	10,114.9	9,215.4	20
Operational systems development	9,872.8	9,876.6	9,066.8	0
Management and support	2,711.1	2,783.1	2,689.4	-2
Exploratory development	2,502.7	2,341.6	2,278.7	7
Research	918.0	891.7	953.7	3
TOTAL RDT&E	\$43,719.0	\$36,945.9	\$33,676.1	18%

^a Estimate. ^b Actual. Source: Department of Defense

Innovative bookkeeping actually reduces 1988 NIH funds

\$ Millions	1988 ^a	1987 ^a		1986 ^a	% change 1987-88
		Appropriated	Revised		
Research project grants	\$3059	\$3397	\$3063	\$2898	-10%
Other research activity	2466	2534	2534	2258	-3
AIDS	344	253	253	135	36
Total obligations less carryover	5869	6184	5850	5289	-5
	-334	—	334	-11	
TOTAL BUDGET AUTHORITY	\$5535	\$6184	\$6184	\$5278	-10%

^a Estimate. ^b Actual. Source: Department of Health & Human Services.

ter scientific careers, an expanded program of support for geographically out-of-the-way universities with relatively weak research programs, and new research programs in materials processes and interfaces, cognitive science, large systems engineering, supercomputer applications, low-temperature chemistry, and storm-scale meteorology.

At the Department of Commerce, the Administration is seeking a 2%, \$25 million, cut to \$1.1 billion in the National Oceanic & Atmospheric Administration's budget. This would entail cutting the budget of the national underseas research program in half to \$5 million in fiscal 1988 and eliminating it entirely by 1989. The coastal zone management and sea grants programs would be phased out by 1990 for savings of some \$80 million per year.

However, funding for the National Bureau of Standards is up 14%, or

\$17 million, to \$139 million under the budget proposal. Funding for the Patent & Trademark Office is up some 38% to \$136 million. Part of the budget increases at these two agencies will be funded through increased users' fees.

Research and development work at the Department of Agriculture is carried out by the Agricultural Research Service. For fiscal 1988, the Administration has proposed a \$16 million, or 3%, increase to \$543 million for ARS, mostly for increased research in the areas of plant and animal productivity. Some \$7 million of the increase, however, goes to additional research in germplasm acquisition, maintenance, evaluation, and enhancement. There is also a related construction proposal to design and build a new national seed storage lab by 1989. This would replace an existing, outmoded storage lab currently at Ft. Collins, Colo.

There is also \$2.1 million for animal productivity research to reduce fat concentrations in livestock by focusing on biochemical and physiological factors to control fat deposition.

The Cooperative State Research Service, which administers funds at the state level for research at universities, gets a significant cut in its funding because of the proposed abolishment of the special research grants program, which was set up to focus attention on specific problems. The Administration has proposed cutting out the entire \$49 million that program is receiving in fiscal 1987, maintaining that the states should use their own funds to solve these problems as they arise. CSRS competitive research grants get a slight increase to \$44.5 million from \$40.7 million, but that includes no additional funds to support research in biotechnology. There

DOE: energy R&D down, defense up

\$ Millions	1988	1987	1986	% change 1987-88
Energy R&D	\$2937.4	\$3077.8	\$2899.4	-5%
General science	814.5	719.2	661.4	13
Supporting research & technical analysis	596.7	639.1	487.7	-7
Magnetic fusion	345.6	345.3	365.5	0
Nuclear energy	336.4	329.3	375.7	2
Environment	288.0	258.0	228.6	12
Clean coal technology	199.1	149.1	99.4	33
Fossil energy	169.4	301.9	296.9	-44
Solar & other renewables	93.6	146.3	171.8	-36
Conservation R&D	80.1	161.7	183.6	-50
Electric energy systems & storage	14.0	27.9	28.8	-50
Defense R&D	2699.5	2425.7	2118.1	11
Weapons R&D, testing	2087.5	1850.3	1582.4	13
Naval reactors development	612.0	575.4	535.7	6
TOTAL	\$5636.9	\$5503.5	\$5017.5	2%

Note: All numbers are estimates. Sources: Department of Energy, S. Repts. 99-397, 99-441

USDA: Total R&D budget is down

\$ Millions	1988 ^a	1987 ^a	1986 ^a	% change 1987-88
Agricultural Research Service	\$542.6	\$526.6	\$489.3	3%
Cooperative State Research Service	240.3	307.9	285.5	-22
Forest Service Research	122.2	125.9	120.1	-3
National Agricultural Library	12.4	11.1	10.8	12
TOTAL	\$917.6	\$971.5	\$905.7	-6%

^a Estimate. ^b Actual. Source: Department of Agriculture

NSF: research funds post big increase

\$ Millions	1986	1987	1988	% change 1987-88
Research & related activities	\$1635	\$1407	\$1294	16%
Mathematical & physical sciences	514	464	435	11
Geosciences	330	285	266	16
Biological, behavioral & social sciences	297	257	239	16
Engineering	205	163	144	26
Computer, information science & engineering	143	117	100	22
Program development & management	95	77	72	23
Scientific, technological & international affairs	51	44	38	16
U.S. Antarctic programs	143	117	110	22
Science & engineering education	115	99	85	16
TOTAL	\$1893	\$1623	\$1489	17%

Note: All numbers are estimates. Sources: National Science Foundation, H. Rept. 99-619

EPA: Superfund gain boosts total R&D

\$ Millions	1986 ^a	1987 ^a	1988 ^b	% change 1987-88
Air	\$ 65.5	\$ 63.0	\$ 66.4	4%
Superfund	59.8	39.5	10.6	51
Energy/acid rain	58.9	59.6	53.6	-1
Hazardous wastes	45.2	50.6	51.4	-11
Toxic substances	29.0	31.1	34.3	-7
Water	24.7	24.4	28.3	1
Drinking water	23.9	24.0	23.3	0
Interdisciplinary	22.9	27.9	28.6	-18
Pesticides	13.2	12.5	11.7	6
Management/support	9.8	9.7	9.6	1
Radiation	1.4	2.7	0.2	-48
TOTAL	\$354.3	\$345.0	\$318.0	3%

a Estimate. b Actual. Source: Environmental Protection Agency

NASA: Space station, research big gainers

\$ Millions	1986 ^a	1987 ^a	1988 ^b	% change 1987-88
Conduct of R&D	\$3623.4	\$3071.7	\$2619.3	18%
Space station	767.0	420.0	200.3	83
Space transportation	568.8	495.5	403.9	15
Physics and astronomy	567.1	522.3	569.3	9
Space applications	559.3	543.7	487.5	3
Aeronautical research	375.0	376.0	337.3	0
Planetary exploration	307.3	356.4	353.6	-14
Space research & technology	250.0	171.0	151.4	46
Life sciences	74.6	72.2	66.1	3
Transatmospheric research	66.0	45.0	—	47
Commercial applications	54.0	41.3	26.8	31
Tracking & data acquisition	18.1	17.1	15.5	6
Safety & reliability	16.2	9.2	7.6	76
R&D facilities	195.5	166.3	137.5	18
TOTAL	\$3818.9	\$3238.0	\$2756.8	18%

a Estimate. b Actual. Source: National Aeronautics & Space Administration

is also a proposal to end construction of new facilities under CSRS. The Administration contends that because the five-year research facility construction program authorized by the 1981 farm bill expires in fiscal 1987, no new funds are needed.

In addition, USDA will be cosponsoring with DOE and NSF a new \$10 million plant science initiative. It will focus on the application of modern techniques in cellular and molecular biology to plants and it will involve the establishment of multidisciplinary basic research and training centers at academic institutions with industrial and local and state government participation.

As a research program, the Environmental Protection Agency's is not large compared to others, but its R&D efforts have far-reaching effects. For fiscal 1988, the Administration has reduced most EPA research activities. Its overall R&D

budget is up 3%, or \$9 million, to \$354 million only because of the expanded work required under the recently passed Superfund reauthorization.

This program, which is supposed to provide health and environmental risk assessments and evaluate demonstrations of commercially developed remedial cleanup technologies, among other things, is slated for a 51%, \$20 million, increase to \$60 million. Unfortunately, the agency's hazardous waste R&D is being cut more than \$5 million. This reflects a reduction of interest in developing new alternatives to land disposal of these wastes.

New requirements in the 1986 Drinking Water Act also are covered in the R&D budget proposal. The emphasis here will be on providing additional control technology data on the effectiveness of pollutant removal technologies and de-

veloping better health effects data. Groundwater research also will be a priority next year.

Acid rain is another program the Administration is highlighting. It has proposed spending \$55.3 million for research on it in fiscal 1988. This is almost the total amount EPA has budgeted for energy-related pollution. The Administration says this will support continued work on evaluation of atmospheric models for acid deposition and more work on aquatic effects and materials damage. EPA also is expected to provide data to the Energy Department for the Clean Coal Technologies program that DOE is doing with Canada. There is some concern, however, that the President has not given the support necessary to begin solving the acid rain problem, and that Congress, with prodding from Canada, may expand the clean coal program significantly. □

An interview with Imperial Chemical
Industries' chairman-designate
Denys Henderson Page 16

FEBRUARY 2, 1987

CHEMICAL & ENGINEERING

NEWS

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High- Performance Fibers

Development for military
and industrial uses expands
Page 9

News of the Week

■ Fourth-quarter 1986 chemical earnings show strong increases, but sales remain at same level for most firms. **Page 4**

■ House science committee hearing reveals members' dissatisfaction with the Administration's handling of science and technology issues. **Page 5**

■ W. R. Grace is indicted on two counts of falsifying information to EPA on the chemicals used and the wastes disposed of at its Woburn, Mass., plant. **Page 5**

■ World's highest-energy particle accelerator goes into operation at Fermilab. **Page 6**

■ Williams Cos. agrees to sell its agricultural fertilizer company to Freeport-McMoRan Resource Partners. **Page 6**

Business

Fuel ethanol producers win two regulatory decisions—one on blending of fuel ethanol with unleaded gasoline, the other on volatility. **Page 14**

Newly formed isotope firm plans to purchase at least 250 of DOE's 1400 gas centrifuges to produce nonradioactive isotopes. **Page 15**

International Business

Denys Henderson, chairman-designate of Imperial Chemical Industries, discusses ICI's worldwide commercial strategy. **Page 16**

Government

National Institutes of Health's 1988 budget faces possible 9% cut as Congress and Administration battle over research funding. **Page 26**

Science

Superconductivity is observed at record high temperatures in inorganic materials by both U.S. and Chinese groups. **Page 29**

Books

Michael Gough's "Dioxin, Agent Orange: The Facts" untangles the social, legal, scientific, and emotional issues. **Page 31**

Cover: Filament winding of rocket motor case
at Hercules' Magna, Utah, plant

Letters	2
Concentrates	
Business	7
Government	22
Science/Technology	28
The Departments	
ACS Comment	33
ACS News	47
Newsprints	48



Cover Story

High-performance fibers are used increasingly for military and industrial applications as a result of their competitive advantages in strength, weight, heat tolerance, and chemical breakdown resistance. **Page 9**

NIH Feels Bite of President's Budget Restraint

Administration proposes 9% cut in available funds for 1988; large part of budget would be deferred to later years to cover current grants

Although basic research generally has fared quite well under President Reagan, there has been some discontent within the Administration over the amount of money being spent at the National Institutes of Health. Last year a major battle erupted between Congress and the Administration over increased research funding for, and the number of grants awarded by, NIH that ended with Congress providing a budget 21% higher than that first proposed by the President.

The Administration appears to be trying to recoup that loss in the fiscal 1988 budget, however. For fiscal 1988, the total NIH request is \$8.2 billion, with more than \$7.8 billion going to fund the research institutes. But all of this money could not be used in 1988. In fact, NIH would spend only \$5.4 billion in 1988; the rest would be deferred to later years. The result is that available funds at NIH for 1988 would be cut 9% compared with Congress' 1987 appropriation.

The Administration simply believes that the amount of funds set by Congress in 1987 to fund nearly 6400 competitive grants and more than 13,000 noncompetitive research projects is just too much. The proposed budget would take a portion of the 1987 appropriation, about \$334 million, and postpone its use until fiscal 1988. A spokesman for the Department of Health & Human Services, of which NIH is part,

says this would reduce 1987 grants awards to about 5700, deferring approval of the other 700 until 1988. Unlike a similar move to cut grants in 1985, the Administration said that this time no changes will be made until Congress approves them.

The smaller number of grants, however, accounts for only \$120 million of the money that is being held back in 1987. The remainder, \$214 million, is going to be saved by decreasing the size of the grants awarded. HHS says this will be done by cutting back the high rate of growth in the size of grants that has been typical of research projects. Office of Management & Budget figures reflect a projected growth in

grant size of less than 5% over the next three years. Actually, OMB's growth calculations allow only a 1.5% annual increase each year, with a contingency fund that would allow funding up to the 5% level. Grant size has been increasing at a rate of about 10% annually. One impact of this lower growth rate figure used by OMB for the multiyear funding is that it will force NIH to examine its historically high inflation rate.

A substantial portion of the NIH budget proposal would provide for multiyear funding of grants awarded in 1987. This money, set at \$508 million in fiscal 1988, would go to fully fund grants awarded this year.

Deferrals, multiyear funding make NIH budget more complex

\$ Millions	1987 appropriation	Carryover to 1988 ^a	Total 1988 request	Outyear funding ^b	Actual new funds for 1988 ^c	% change 1987-88 ^d
National Institutes	\$5564.8	\$333.0	\$7841.4	\$2717.3	\$5113.8	-8%
Cancer	1402.8	64.1	1811.1	508.3	1302.8	-7
Heart, Lung & Blood	930.0	56.6	1274.4	452.5	821.9	-12
General Medical Sciences	570.9	44.9	873.6	391.5	482.0	-16
Allergy & Infectious Diseases	545.5	26.4	815.3	264.2	551.1	2
Diabetes & Digestive & Kidney Diseases	511.1	35.4	767.6	327.1	440.4	-14
Neurological & Communicative Disorders & Stroke	490.2	35.0	677.5	254.3	423.2	-14
Child Health & Human Development	366.8	23.4	493.2	171.2	322.0	-12
Eye	216.6	15.2	295.7	110.9	184.8	-15
Environmental Health Sciences	209.3	6.3	239.9	41.4	198.4	-5
Aging	176.9	11.0	237.9	81.8	156.2	-12
Arthritis & Musculoskeletal & Skin Diseases	138.7	9.1	201.1	78.1	123.0	-11
Dental	117.9	5.6	144.1	36.0	108.0	-8
Research resources	322.9	0.0	263.3	0.0	263.3	-18
National Library of Medicine	61.8	0.0	64.4	0.0	64.4	4
Center for Nursing Research	19.0	1.5	24.9	8.7	16.1	-15
John E. Fogarty Center	11.4	0.0	11.6	0.0	11.6	2
Research facilities	31.9	0.0	5.0	0.0	5.0	-84
TOTAL	\$6011.8	\$334.5	\$8200.6	\$2726.0	\$5474.2	-9%

^a Funds that the Administration requests be deferred from fiscal 1987 and spent in fiscal 1988. ^b Funds requested for fiscal 1988, but not to be used until 1989 and 1990 to cover grants this year. ^c Only new funds for 1988; actual spending would include the carryover 1987 funds, thus making the 1988 spending slightly higher. ^d Change is difference between 1987 appropriation and base funding request for 1988. Source: Department of Health & Human Services

HHS says that, if Congress approves the process, in three or four years, all NIH grants would receive full advanced funding. HHS budget personnel say this really has no effect on the NIH budget but is being done as a way to reveal the rapidly rising costs of NIH grants and to get Congress to consider reducing costs.

One group committed to action against the reduced spending proposal is the Ad Hoc Group for Medical Research Funding. The organization comprises about 150 groups that lobby for research funds for NIH and the Alcohol, Drug Abuse & Mental Health Administration. David Baime, a spokesman for the group and an analyst for the Association of American Medical Colleges, says its members are extremely upset about the President's proposal and are considering some kind of legal action. Baime says the group is concerned that NIH will be forced to take some action based on the proposed budget before the changes can be properly considered by Congress. He is afraid that the proposal could cut research grant size by almost 10%, on average, meaning that researchers would be receiving less money than expected and would have to cut back on the scope of their projects that have already been approved. OMB's projections of having grants grow at 1.5% annually is totally unrealistic and just adds to the confusion, Baime says.

Baime and others contacted about the proposed budget do not think Congress will enact legislation approving the changes as recommended. There remains very strong support for NIH in Congress, as shown by the large increase in appropriations passed last October. And that is not likely to be swayed by the spreadsheet gymnastics the executive branch is using to point up the high cost of biomedical research. Baime says the ad hoc group is close to suing the Administration to ensure that none of the proposed changes are implemented before Congress acts. Such a move would have to come soon, he says, because there are already indications that OMB may be setting NIH up as the "bad guy" if NIH is forced to make cuts in grant funding.

David Hanson, Washington

Federal alert—new legislation

This C&EN listing highlights legislation introduced in Congress between Jan. 6 and 12. House and Senate bills are listed under subject area by number, primary sponsor, and committee to which they were referred.

HOUSE

Environment. H.R. 463—Coleman (R.-Mo.). Requires notification of local, state, and federal officials of storage of suspended or cancelled pesticides, and permits EPA inspection of storage sites; referred to Agriculture.

Intellectual property. H.R. 557—Fish (R.-N.Y.). Modifies application of antitrust laws to encourage licensing of patented inventions; referred to Judiciary.

Trade. H.R. 507—Neal (D.-N.C.). Requires President to take retaliatory action against foreign barriers and restrictions that unfairly limit U.S. trade; referred to Ways & Means.

SENATE

Energy. S. 85—Johnston (D.-La.). Repeals natural gas end-use limitations in Powerplant & Industrial Fuel Use Act of 1978, and incremental pricing requirements in Title II of Natural Gas Policy Act of 1978; referred to Energy & Natural Resources.

Environment. S. 1—Byrd (D.-W.Va.). Amends Clean Water Act, sets new restrictions on industry waivers from national discharge standards, and extends deadlines for compliance with new technology-based standards; referred to Environment & Public Works.

S. 20—Moynihan (D.-N.Y.). Directs EPA to establish water quality criteria for 100 groundwater contaminants, and provide states with documents specifying physical, chemical, biological, and radiological properties of contaminants, plus risk they pose to human health at various concentrations; referred to Environment & Public Works.

S. 95—Kerry (D.-Mass.). Aims at controlling acid rain by reducing annual emissions of sulfur dioxide 12 million tons and of nitrogen oxides 3 million tons by 1995 in 48 contiguous states; referred to Environment & Public Works.

S. 235—Wilson (R.-Calif.). Gives EPA, rather than Interior, authority to regulate air pollution caused by oil and gas production operations on outer continental shelf; referred to Environment & Public Works.

S. 300—Stafford (R.-Vt.). Reduces sulfur and nitrogen oxide emissions from industrial plants and vehicles over a 10-year period; referred to Environment & Public Works.

Health. S. 79—Metzenbaum (D.-Ohio). Provides for notification of workers at risk of occupational diseases to establish system

for identifying and preventing illness and death of such workers; referred to Labor & Human Resources.

S. 223—Gore (D.-Tenn.). Makes FDA an independent entity, separate from Department of Health & Human Services, with independent commissioner appointed by President; referred to Labor & Human Resources.

Liability. S. 217—Pressler (R.-S.D.). Makes each defendant in liability case responsible only for amount of damages allocated to it in direct proportion to defendant's percentage of responsibility for damages claimed; referred to Judiciary.

Nuclear. S. 14—Byrd (D.-W.Va.). Establishes independent, three-member Nuclear Safety Board to investigate accidents at nuclear power facilities, along with policies and practices that may have led to them; referred to Environment & Public Works.

S. 44—Moynihan (D.-N.Y.). Establishes insurance system designed to provide full compensation of public in event of nuclear accident; referred to Environment & Public Works.

Science. S. 52—Pressler (R.-S.D.). Directs secretaries of Energy and Interior and NSF Director to prepare report on objectives, costs, and benefits of Continental Scientific Drilling Program; referred to Energy & Natural Resources.

Taxes. S. 58—Danforth (R.-Mo.). Provides permanent tax credit for increased R&D expenditures, restores credit rate to 25%; referred to Finance.

S. 200—Nickles (R.-Okla.). Repeals windfall profit tax on crude oil; referred to Finance.

S. 302—Boren (D.-Okla.). Imposes a new tax on the importation of crude oil and refined petroleum products; referred to Finance.

Trade. S. 180—Riegle (D.-Mich.). Establishes Department of International Trade & Industry in executive branch of government; referred to Governmental Affairs.

S. 186—Riegle (D.-Mich.). Establishes national trade information policy, Council on Trade Information, U.S. Trade Data Bank; referred to Governmental Affairs.

S. 219—Sasser (D.-Tenn.). Reforms and streamlines procedures to be followed in obtaining relief from injuries caused by import competition and unfair trade practices; referred to Finance.

S. 259—Chiles (D.-Fla.). Creates Cabinet-level Department of Trade charged with identifying and removing both U.S. and foreign barriers to free trade, monitoring foreign industries that engage in predatory practices, and requires counteractions against other countries that refuse to open their markets to imports; referred to Governmental Affairs.

FINAL PROGRAM
ACS spring meeting in Denver
Page 31

FEBRUARY 9, 1987

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Petrochemicals

Capacity limitations hit ethylene
Page 9

News of the Week

■ Experts in chemical hazard prevention examine the chemical industry's response to the regulatory revolution in the world of chemical safety. **Page 4**

■ Reinforced plastics and composites will do even better in 1987 than in 1986, as a result of the continuing emergence of products and new applications for composites. **Page 5**

■ First rotary slagging kiln dedicated solely to incineration of PCBs has begun commercial operation in Kansas. **Page 5**

■ Chemical trade surplus last year totaled \$7.77 billion, a rise of 8% from 1985 and a reversal of a five-year downward trend. **Page 6**

International Business

U.K. chemical industry's prospects look bright for 1987, as capacity use and domestic sales increase. **Page 14**

Canadian plastics processors, coming off a good year in 1986, expect even higher sales and profits in 1987. **Page 17**

Government

In 1987, House Science, Space & Technology Committee will debate a broad range of science policy issues. **Page 19**

EPA updates hazardous waste sites list, adding 64 sites and removing one, which brings the total on its national priorities list to 951. **Page 21**

Science

A new method to make cyclic disulfides routinely has been developed by a team of chemists at the University of Montreal. **Page 23**

Technology

Neutron detector based on polyacetylene, a conductive organic polymer, offers advantages over previous detection methods. **Page 24**

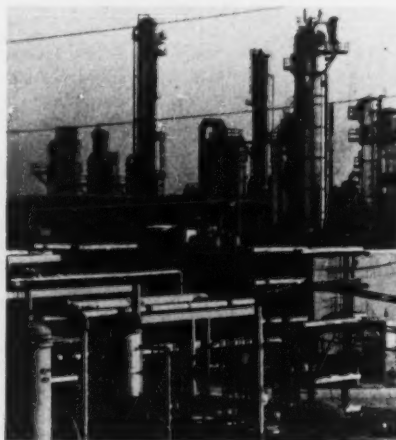
New attrition-resistant catalyst makes use of transport-bed technology possible in the production of maleic anhydride. **Page 24**

Final Program

Program for 193rd ACS National Meeting in Denver includes listing of all technical papers and exposition exhibitors, registration form. **Page 31**

Cover: Union Carbide's ethylene derivatives plant in Texas City, Tex.

Letters	2
Concentrates	
Business	7
Government	18
Science/Technology	22
The Departments	
ACS News	25
Meetings	107
Newsclips	120



Business

Basic petrochemicals production will continue to climb in 1987; record volumes are predicted for ethylene and propylene with prices strengthening and profits improving. **Page 9**

Molten glass flowing over the refractory inner surface of the kiln promotes high temperatures and good heat transfer. The glass encapsulates combustion residue in a nonleachable solid that can be disposed of in approved landfills. Combustion gases pass to an afterburner. There, the company says, efficiency of destruction and removal exceeds Environmental Protection Agency standards.

PCBs were used as dielectric fluids in transformers, capacitors, and circuit breakers until the early 1970s. At that time, their use ceased, owing to evidence that PCBs cause human skin and liver disease, and cancer and birth defects in lab animals.

EPA estimates that about 150,000 transformers are still in use in the U.S., containing a total of 300 million lb of PCBs. In addition, PCBs contaminate dielectric fluids of a few million capacitors and other

transformers, resulting from residues left behind as fluids have been replaced over the years.

Pyrochem spokesmen say that the speed and efficiency of its incineration process enables them to issue certificates of destruction to clients promptly at the completion of each job. Also, the company is equipped to keep careful records of the receipt and destruction of PCBs and contaminated oils, soil, clothing, and debris.

Other Westinghouse PCB services include risk analysis at customer plants and analyses of fluids and solids. The firm also has a process to remove old fluid from a transformer and circulate a proprietary dielectric fluid through the transformer for six to nine months while it remains in full operation. As the dielectric circulates outside the transformer, another unit removes PCBs from it before return. □

outlook for chemical trade still looked bleak. In the first quarter, the surplus was down 19% from first-quarter 1985 to \$1.70 billion. Exports of chemicals and allied products during those three months were down 2% to about \$5.60 billion. And chemical imports were still increasing rapidly, rising 8% to \$3.89 billion.

The situation turned around in the second quarter. Chemical exports rose 3% from 1985's second quarter to \$5.64 billion, and imports actually fell 5.0% to \$3.74 billion. In that quarter, the surplus rose 27% from second-quarter 1985 to almost \$1.90 billion. That was enough to bring the surplus in the year's first half even with the first six months of 1985 at \$3.60 billion, on a 1% increase in exports to \$11.2 billion and a 1% increase in imports to \$7.63 billion.

In the third quarter, the surplus showed some retrenchment, with exports rising 5% from the year-earlier quarter to \$5.79 billion, but imports climbing 10% to \$3.70 billion. Thus, the surplus fell 1.7% from the previous year's third quarter to about \$2.09 billion.

It was the fourth quarter's strong performance that really turned the year's chemical trade surplus upward. Exports totaled \$5.74 billion, a 12% gain from 1985's fourth quarter, and imports increased just 1% to \$3.67 billion. Thus, the surplus increased almost 39% to \$2.07 billion.

December figures, released late last month, show the best results of the year. Chemical exports in December amounted to \$1.91 billion, up less than 1% from the previous month but 16% more than in December 1985. Imports, meantime, totaled \$1.21 billion, down 11% from November but still up almost 4% from a year earlier. The December surplus totaled almost \$700 million, a month-to-month gain of 29% and an annual increase of 47%.

December's was the best year-to-year increase in the surplus for any month in 1986 and it completed a four-month string of healthy double-digit annual gains. In September the trade surplus jumped 33% from a year earlier, in October 31%, and in November 41%. □

Chemical trade surplus rebounds

In a year when the U.S. trade deficit hit record levels in spite of a steadily eroding dollar, the chemical industry saw the decline of its trade surplus halted and a recovery begin.

Chemicals, one of only a handful of U.S. industries to continually show more exports than imports, had been in a decline since its trade balance hit a peak in 1980, according to figures from the Commerce Department.

Between 1980 and 1985, the chemical trade surplus declined almost 41% to about \$7.23 billion. Exports of chemicals and products during that time rose just 5%, or an average

annual rate of just 1%, to a value of about \$21.8 billion. Meanwhile, imports increased 70% to about \$14.5 billion, an average annual growth rate of about 11%. Thus, the trade surplus for chemicals fell at an average yearly rate of nearly 10%.

Last year brought a turnaround, however. Although the trade surplus still has a long way to go to get back to its 1980 peak, it has recovered somewhat. The surplus in 1986 rose almost 8% from 1985 to \$7.77 billion. Chemical exports rose 5% to a value of \$22.8 billion. Imports also increased, but at just 3%, to total \$15.0 billion.

During the first part of 1986, the

Chemical trade surplus ended slide last year

\$ Billions	1986	1985	1984	1983	1982	1981	1980
Exports	\$22.77	\$21.76	\$22.31	\$19.79	\$19.89	\$21.19	\$20.74
% change from previous year	4.6%	-2.5%	12.7%	-0.5%	-6.1%	2.2%	19.8%
Imports	15.00	14.53	13.69	10.80	9.49	9.32	8.54
% change from previous year	3.2%	6.2%	26.7%	13.8%	1.8%	9.1%	14.1%
Surplus	7.77	7.23	8.62	8.98	10.40	11.87	12.20
% change from previous year	7.5%	-16.2%	-4.0%	-13.6%	-12.4%	-2.7%	24.2%

Production of Basic Petrochemicals Will Continue Upward in 1987

Record volumes will be set for ethylene and propylene as prices strengthen following mid-1986 decline and improve producers' profitability

Bruce F. Greek, C&EN Houston

Good times have returned for producers and sellers of basic petrochemicals—some of the best times in nearly a decade.

Demand for ethylene and propylene for chemical and polymer uses will hit new highs again in 1987 as prices are strengthening following the precipitous decline of mid-1986. Benzene output also may grow more in 1987 than in the past four years. Other basic petrochemicals and many of their derivatives are being produced in record volumes and are returning a better profit than producers have had so far in the 1980s.

The outlook beyond 1987, even with capacity to make some of these petrochemicals now operating at ef-

fective limits, remains conservative, with no major round of plant construction.

Selling prices of most basic petrochemicals increased late in 1986, after following the decline in crude oil prices early in 1986. Further price increases have been made already in 1987, with most industry observers expecting more to occur, as long

Key Chemicals

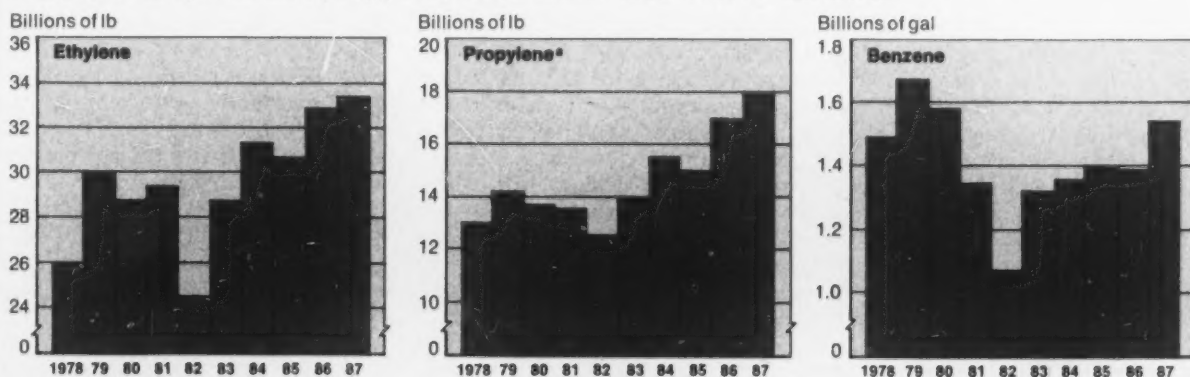
as crude oil prices hold. Despite combined increases, however, prices haven't risen enough to allow returns on investment to reach levels at which more capacity can be built, even with lower overall construction costs than five years ago. As a result, capacity increases for basic petrochemicals will be small throughout the rest of this decade.

Aside from the low return on investment, many industry planners question whether the current increases in end-use demand can be sustained and whether demands will

be filled as in the past. Demand growth rates last year for many first- and second-line derivatives were double or more the average growth rates of the previous five years. Such current economic factors as low interest rates and strong consumer spending led to the high growth. Should the economy slow, then the growth in demand for products made of the basic petrochemicals could reverse, as sales decline and inventories build. Most forecasts for growth in basic petrochemicals in 1987 are about half their 1986 rate, because of the expected slower demand growth.

A significant part of basic petrochemical production is exported as derivatives. These exports have a growing competition from new production in other countries in spite of a weaker dollar. If exports of the derivatives, and products made from them, decline, then the U.S. market will have to absorb the loss in exports to sustain production growth. The loss in exports, in effect, would reduce the need to expand capacity. If exports then are replaced by imports produced by competing for-

Output of ethylene and propylene rises faster than that of benzene



* Used for chemicals and polymers. Sources: U.S. International Trade Commission, C&EN estimates

Smaller-volume petrochemicals, butadiene and *p*-xylene, continue to grow

Two important smaller-volume basic petrochemicals—*butadiene* and *p*-xylene—continue to grow steadily. Butadiene output this year will approach 3 billion lb, and *p*-xylene output will top 5.25 billion lb. These two petrochemicals as well as others such as *o*-xylene, toluene, and the butenes have less diverse derivative patterns than do ethylene, propylene, and benzene. Consequently, they are subject to the fluctuations of a single industry.

Butadiene goes largely to make elastomers, with tires dominating the end uses. Among other uses, high-performance plastics are fast growing. Because of improvements in the elastomers themselves, as well as in carbon black and other materials used as reinforcements, and in tire design and construction, tire life has increased greatly. And if the effect of the shift toward lighter cars is included, tire life for most motorists has more than doubled over the past 10 years.

Because tire manufacturing has slowed, butadiene output has dropped drastically since 1979. Imports have increased and at times accounted for a quarter of U.S. demand. This year, imports will drop to about 10% of U.S. consumption. Most butadiene now

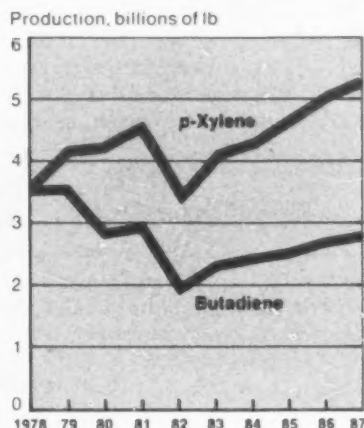
is a coproduct of steam cracking to make ethylene.

Butadiene prices fell during 1986 more than other basic petrochemical prices, caused by further slowing of demand and a surge of imports. Prices in 1986 reached their nadir in October, at about 9 cents per lb, after rising as high as 29 cents per lb in January. But prices have recovered because of a rapid decline in imports from Europe. Prices, now in the range of 13 to 14 cents per lb, are expected

to rise, if crude oil prices remain at current levels or rise.

The situation for *p*-xylene has both similarities to and differences from that of butadiene. It has but two major markets—in making either dimethyl terephthalate or purified terephthalic acid for polyesters and for export. The polyester use is dominated by one market—fibers—which is experiencing stiff competition from imported apparel containing polyester fibers. The rest of polyester consumption is mostly as films and bottles. Both of these end uses are growing, with polyester bottle resin production expected to increase more than 10% this year.

Exports of *p*-xylene probably exceeded 1 billion lb in 1986, out of total production of about 5 billion lb. New capacity has just come on stream in Japan, and more is expected during the second quarter, which will reduce exports in 1987 as much as 10%, if the plants operate well this year. However, growth in demand for polyester resins in the U.S. is expected to more than compensate for the decline in exports. Prices, now at about 17 cents per lb, probably will rise as much as other petrochemical prices during the rest of 1987.



Sources: U.S. International Trade Commission, C&EN estimates

eign plants, the U.S. capacity would be needed even less.

As the world's basic petrochemical industry becomes more widespread, trade increases between producers, in addition to the industry supplying nonproducing areas. If U.S. consumers find it costs less to import either basic petrochemicals or derivatives to meet their needs, then U.S. capacity might be shut down, as has occurred in the 1980s. The further rise anticipated in imports of crude oil, at somewhat higher prices, will reduce the competitive position of U.S. petrochemicals in world markets and will make capacity expansions less needed.

Petrochemical capacity continues to be built in foreign countries even though there is a slight overcapacity in the world. The latest major development, for example, is in South Korea, where Yukong Ltd. has contracted with M. W. Kellogg

to build a steam cracker using Kellogg's Millisecond furnace technology with a capacity of 250,000 metric tons per year of ethylene. Derivatives of the ethylene and other petrochemicals made in the unit will reduce U.S. exports of the derivatives. The derivatives often are made into consumer goods and subsequently exported to the U.S. and other countries, which potentially reduces both U.S. consumption and exports and, in turn, the need to expand basic petrochemical production.

In the U.S., demand for petrochemicals will continue to grow but at rates of a quarter to half the rates a decade ago. New derivatives of petrochemicals and new uses will add to demand above that due to population growth. The growth in demand, although fractionally small, will be large in volume, so capacity expansions will be needed.

To be feasible, expansions would have to cost far less than the cost of building a new plant, a situation familiar to the ethylene industry. Capacity actually is expanded constantly at ethylene plants, the size of expansion varying with the operating situation. During scheduled maintenance shutdowns, extensive debottlenecking is done, often raising operable capacity as much as 10%. Because maintenance shutdowns are done as infrequently as three-year intervals, the average capacity gain fits the typical pattern now of about 3% annually.

Until the early 1990s, capacity expansion needed in the basic petrochemicals, especially capacity expansion needed for ethylene, will be made this way.

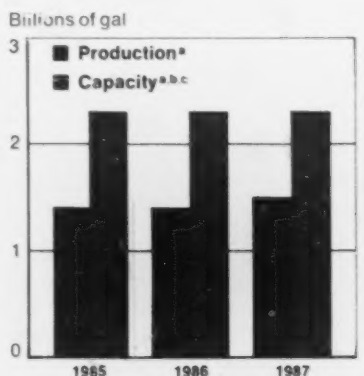
For details of the near-term outlook for three of the largest basic petrochemicals, please see the following pages.



Benzene

- **Output to rise slightly**
- **Capacity on hold**
- **Prices up and volatile**

PRODUCTION/CAPACITY



^a All sources, nonfuel uses. ^b First quarter. ^c Limited by purification facilities available

MAJOR PRODUCERS

Chevron Chemical, Dow Chemical, Exxon Chemical, Shell Chemical, Standard Oil Chemical

HOW MADE

Catalytic reforming and thermal (steam) cracking of petroleum hydrocarbons; coking of coal; dealkylation of toluene

MAJOR DERIVATIVES

Ethylbenzene 55%, cumene 20%, cyclohexane 15%, nitrobenzene 5%

MAJOR END USES

Fabricated plastics and elastomers 55%, phenolic resins 20%, nylons 15%

FOREIGN TRADE

Exports less than 10 million gal; imports about 175 million gal

PRICE

Between \$1.00 and \$1.15 per gal

The outlook for benzene in 1987 is for somewhat better demand growth. Prices for this basic aromatic are volatile. On the large spot market centered around Houston, prices declined from \$1.15 or more per gal as the year opened to about \$1.05 per gal now.

As for other petrochemicals, the price of benzene directly reflects the cost of its main raw material—crude oil. Currently, to a lesser degree, benzene's price is affected by small changes in demand, for example, the current strong demand for its major derivative, styrene. However, some styrene plants are shut down for maintenance at this time, reducing benzene demand and prices and making styrene temporarily in short supply.

Benzene demand has changed little in recent years. Except for the recession year of 1982, benzene production in the U.S. has been in the range of 1.3 billion to 1.4 billion gal annually since 1980. This range is off about 15% from the peak production of 1.67 billion gal in 1979. In 1987, production may rise enough to bring the total to nearly 1.5 billion gal (11 billion lb).

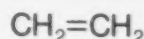
Capacity to make and purify benzene also has declined to about 2.30 billion gal from the peak of 2.59 billion gal at the beginning of 1981. Capacity estimates vary because of assumptions that must be made about the feedstock for producing units and about their operating conditions. Some of the currently available capacity isn't operating because the source—a refinery catalytic reforming unit or an ethylene plant—has been shut down. Operation of other production facilities—such as those used to dealkylate or disproportionate toluene—is dependent on the spread between the values of toluene and benzene or on whether sufficient demand exists for the coproduct xylenes. These latter units can be started up relatively easily when costs suggest that a profit can be made by operating them. When shut down, the units often are fully

depreciated and have little capital charges against them.

If benzene production in 1987 reaches 1.5 billion gal and the average operating capacity for extraction and purification this year totals 2.3 billion gal, then the average operating rate will be 65%. At this level of operation, and with prices volatile, only a minor return on investment would be made by producers, allowing little, if any, capacity expansion (even by debottlenecking).

Small growth in benzene output during the 1980s resulted partly from the lackluster performances by several large-volume derivatives, the most important being styrene. Styrene's raw material, ethylbenzene, accounts for more than 55% of U.S. benzene consumption. Another derivative, cyclohexane, is still well below its peak benzene consumption of 262 million gal set in 1979. Cumene, nitrobenzene (aniline), detergent alkylates, chlorinated benzenes, and other uses all fell below previous consumption levels during the last recession, and some are not yet back to previous demand levels. The consumption in making maleic anhydride fell to about zero from nearly 50 million gal as technology to oxidize *n*-butane took over.

Benzene consumption in making chemicals is expected to rise in 1987 mainly because of increased production of styrene, cyclohexane, and cumene. Final consumption of much of these derivatives will depend on housing construction, which is expected to increase because of low interest rates. This year's increased demand for benzene in these areas will continue the pickup that began during the second half of 1986. It will continue through the first half of this year at least. For all of 1987, U.S. consumption in these uses will be up 3 to 4%. Benzene production, however, may have a smaller increase, of 1 to 2%, because imports could rise while exports of derivatives, such as ethylbenzene, may decline.

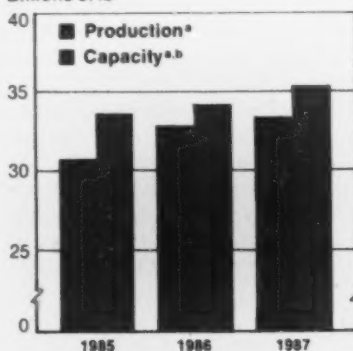


Ethylene

- **Production to grow**
- **Capacity up modestly**
- **Prices climbing**

PRODUCTION/CAPACITY

Billions of lb



^a All sources ^b First-quarter operating capacity; additional 2.5 billion to 4.0 billion lb shutdown possibly available depending on economics.

MAJOR PRODUCERS

Amoco Chemicals, Exxon Chemical, Dow Chemical, Lyondell Petrochemical (Arco), Shell Chemical

HOW MADE

Thermal (steam) and catalytic cracking of hydrocarbons ranging from ethane to heavy gas oil

MAJOR DERIVATIVES

Polymers 50%, ethylene oxide 15%, ethylene dichloride 15%, ethylbenzene 10%, linear alcohols 5%

MAJOR END USES

Fabricated plastics 75%, antifreeze 10%, fibers 5%

FOREIGN TRADE

As monomer, exports about 325 million lb; imports 375 million lb

PRICE

14.5 to 15.5 cents per lb

Strong demand for ethylene in 1987 will require plants to be run at effective capacity. Despite the demand, capacity expansions for the year will be limited to debottlenecking efforts. Although producers can sell all of this olefin they can make, it is unlikely that prices will rise enough to cover additional plant capital costs.

Ethylene production in 1987 may reach a new high of 33.5 billion lb, but it's more likely to be a little short of that because of capacity limitations and maintenance shutdowns. Output growth for ethylene this year will not be so large as in 1986 when production rose an estimated 2.2 billion lb, or more than 7% over 1985 production, when, for the first time, the total rose above 30 billion lb. Production increases during 1987 likely will be held to the range of 500 million to 700 million lb, an increase of about 2%.

Because of modification to and restarting of a long-shutdown unit by Occidental Chemical and some debottlenecking by almost all producers during 1986, nameplate total of operating ethylene capacity has been revised from 34 billion lb upward to 35.1 billion lb. In 1987, the operating capacity is expected to expand about 2% because of the continuing debottlenecking programs by producers. Such increases in capacity will somewhat offset losses due to temporary shutdowns. The average operating rate for 1987 thus will be very close to the effective capacity.

Most ethylene sold under contract currently brings producers about 15 cents per lb. Price increases of crude oil and natural gas liquids could cause the ethylene price to rise later on. Unless the selling prices rise substantially, shut-down plants will not likely be restarted. The plants are down because they are less efficient in energy requirements and other operating costs than are plants now running. Moreover, considerable time and expense would be needed to start them.

The outcome will be varying de-

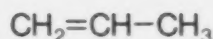
grees of tightness in ethylene supply throughout most of 1987. The ethylene inventory, believed to be less than 1 billion lb, was drawn down again in 1986 to meet demands and may be at a minimal level of less than two weeks' supply. Should mechanical problems develop in plants, ethylene supply could become very tight at times during this year and be reflected in volatile prices, especially in the small spot market.

Pricing and tightness of supply depend heavily on a few major derivatives of ethylene. In 1986, all of these derivatives showed production gains. Some, such as high-density polyethylene and polyvinyl chloride, grew at 6 or 7%, unusually well for large-volume products. Vinyl chloride production was up more than 8% in 1986 (C&EN, Jan. 5, page 10), reflecting increased exports as well as more polymerization. A few small uses of ethylene—synthetic ethanol, for example—fell in 1986.

Demand growth for ethylene derivatives has been forecast to be lower in 1987 than in 1986, because of anticipated slower growth in the economy. Low interest rates, however, again could spur sales of houses and autos as well as consumer nondurables, boosting demand growth for ethylene derivatives to nearly the 1986 rate. Meeting demands for derivatives has become as limited as for ethylene itself, governed by capacity availability. Exports of derivatives could decline and imports rise as a result of rising demand and prices.

If demand for ethylene derivatives were to push up their prices, then ethylene producers might receive some added revenue. If that is the case, producers can shift operations to gain output. For example, they might start using more light hydrocarbons in plants designed to handle a wide range of hydrocarbons. Feedstock and operating costs would increase, but such increases could be recovered by higher selling prices spread over greater output. Then, ethylene production could rise more than is now forecast.

Key Chemicals

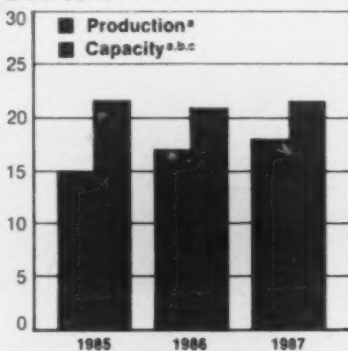


Propylene

- **Production growing**
- **Capacity in excess**
- **Prices firming**

PRODUCTION/CAPACITY

Billions of lb



^a All sources, nonfuel uses. ^b First quarter. ^c Limited by purification facilities available.

MAJOR PRODUCERS

Amoco Chemicals, Chevron Chemical, Exxon Chemical, Lyondell Petrochemical (Arco), Shell Chemical

HOW MADE

Thermal (steam) and catalytic cracking of hydrocarbons

MAJOR DERIVATIVES

Polymers 40%, acrylonitrile 15%, propylene oxide 10%, cumene 10%

MAJOR END USES

Fabricated plastics, resins, and elastomers 65%, fibers 15%

FOREIGN TRADE

Exports rising to more than 750 million lb; imports holding at about 350 million lb

PRICES

Chemical grade 9.5 cents per lb; polymer grade 10.5 cents per lb

This year propylene production for making chemicals and polymers will increase more slowly than during 1986. Strong demand for polypropylene, modest growth in other large propylene uses, and a fairly large rise in exports to Europe are behind the expected propylene output growth. Prices for both chemical and polymer grades of propylene will continue to fluctuate with the price of crude oil.

Propylene capacity, based on the size of purification facilities, easily can handle this year's demand growth. Capacity of these facilities to purify propylene to refinery grade (as low as 30%, but usually 50 to 75%), to chemical grade (90 to 95%), or to polymer grade (99% plus) exceeds 21.5 billion lb. Actual productive capacity for propylene could be greater than the 35 billion lb of ethylene capacity, if refinery and steam cracking sources are combined and the feedstocks used are such that high propylene yields will result. In addition to size of purification facilities, propylene for chemical and polymer uses is limited by the competition for it in fuel uses.

U.S. production of propylene for chemical and polymer uses will total about 18 billion lb this year, up about 6% from the 17 billion lb estimated for 1986. The 1987 gain will be half last year's gain, as derivative growth, especially polypropylene, meets capacity limitations. The 18 billion lb output will require the nominal 21.5 billion lb of capacity to be run at a rate of about 85%. That rate will not be high enough to stimulate very much expansion through debottlenecking.

The consumption pattern for propylene will change little except for a continuing increase in the share going to polypropylene and for rising exports to Europe. The surge in exports of propylene is expected to be short-lived, as European producers meet higher demands and prices by taking more from refinery production (which will increase as catalytic cracking increases in Europe).

A large share of propylene derivatives also is exported—equivalent to as much as 15% of U.S. propylene production this year.

Polypropylene leads the list of derivative exports. These exports, plus increasing U.S. demand, raised polypropylene production in 1986 to nearly 5.8 billion lb, up well over 12% from 1985. In 1986, polypropylene plants were operated at about 95% of nameplate capacity, which was their practical limit. A small amount of additional capacity for polypropylene will be coming on stream this year, but production will grow more slowly than last year as a result of capacity limitations. Consequently, demand for propylene used to make polymers—almost 40% of chemical and polymer uses—will grow more slowly in 1987. Nevertheless, demand for making polymers will grow faster than will demand for propylene in any of the other major derivatives.

Acrylonitrile, propylene oxide, cumene, various oxo chemicals, the oligomers, and isopropyl alcohol account for most of the remaining chemical consumption of propylene. None of these derivatives are forecast to grow very rapidly, because their end uses are not growing much.

With low growth expected in propylene demand in 1987 and with the apparent large capacity available, prices are expected to remain stable, rising only to reflect any higher crude oil prices. The effective halt in use of lead alkyls for increasing octane values in gasoline, however, will increase the value of propylene to refiners making alkylate. Chemical and polymer uses will have to pay the alternate value of propylene in gasoline components, plus purification costs, to obtain supplies from refinery production. This competition will increase prices slightly but will have little effect on chemical and polymer consumption, because these costs are relatively small and can be passed through to consumers of propylene derivatives.

Good Growth Forecast for U.K. Chemical Industry

Strong gains are expected in domestic demand, production, and exports over last year; prospects also are brighter for other European nations

Dermot A. O'Sullivan, C&EN London

The message from the U.K. Chemical Industries Association's recent annual Business Outlook conference in London is encouraging. "The industry's prospects for 1987 look bright," says Richard D. Freeman, chief economist for Imperial Chemical Industries. And, he adds, "we believe that 1988 will be another reasonably good year. It is an encouraging prospect that I hope can be achieved and extended in 1989."

Freeman was presenting conclusions reached by the CIA forecasting panel, which he chairs. Although these conclusions center largely on the state of the industry in the U.K., he and others at the conference broadened their vision

to embrace Western Europe as a whole.

He and his associates expect U.K. domestic demand for chemicals this year to be more than 4% higher than last year. In this, they may appear to be going out on a limb somewhat considering that 1985 showed a mere 1% improvement, and last year brought a slight decline.

The panel is forecasting a substantial increase in the U.K.'s chemical export volumes, probably 6% ahead of 1986. That would be nearly double 1986's export growth over 1985. The anticipated 7% rise in the level of imports will be a fraction below 1986's import volume growth over 1985.

Movements in the exchange rate of the British pound against other currencies is a critical factor in these export and import projections, Freeman acknowledges. "In this respect, the most important are the West German deutsche mark and the dollar," he notes.

For instance, the pound sterling has been losing ground against the mark during the past 18 months or



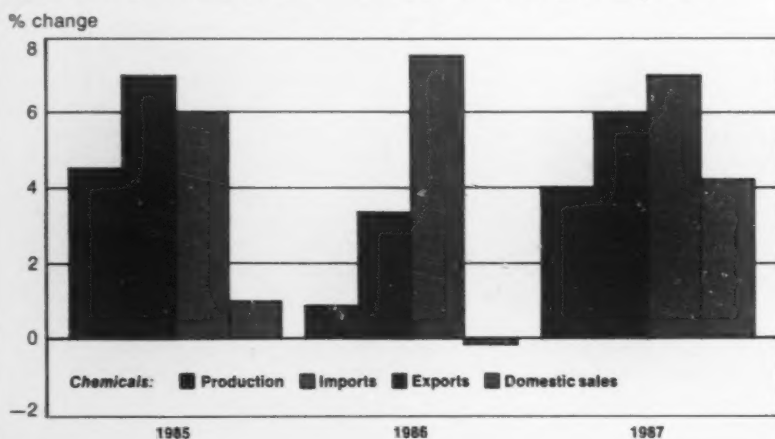
Freeman: much higher profitability

so. Compared with an exchange rate of more than four to the pound in mid-1985 (which was down from about five marks early in 1981), it now stands at less than three. "For purposes of the forecasts, we have assumed a deutsche mark-to-sterling average of 2.85 for this year. This represents an average depreciation of sterling against the deutsche mark of 10.5% compared with 1986," Freeman remarks.

As for the dollar, he expects the 1986 average of about \$1.45 to the pound to remain essentially the same this year. It may not turn out to be the case, however. The dollar continued to weaken in January. By the end of the month it had moved to around \$1.55 to the pound.

"Taking the sterling index [its weighted average value against a basket of currencies], the forecasting panel is assuming an overall fall of around 6% this year. We have, therefore, built a considerable improvement in competitiveness from

U.K. domestic sales of chemicals will show sharp rise



the exchange rate into the forecasts," he points out. "Moreover, the U.K. will hold the advantage in terms of unit labor costs measured in a common currency," he adds.

The cost of oil, both as an energy source and as feedstock for petrochemicals, will influence the outcome of chemical companies' business results, as it has in the past. Ironically, selling prices of chemicals came under pressure in 1986 reflecting the decline in the oil price. This year, prices are expected to stop falling in Europe, or even rise a little, as demand strengthens, and because of an assumed rise in oil prices to about \$18 a barrel. "Profitability in the [chemical] industry should show a considerable improvement this year compared with 1985 and 1986," Freeman predicts.

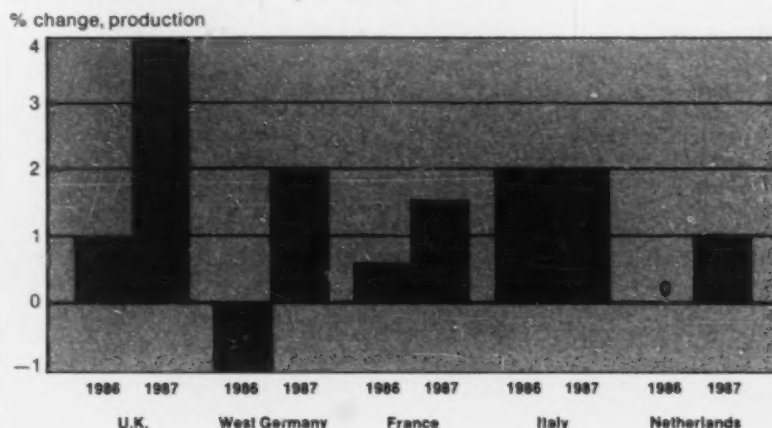
Overall, chemical production in the U.K. this year likely will exceed 1986's by 4%. That's twice the increase foreseen for West Germany and Italy, and compares with a 1.5% advance in France and 1% in the Netherlands.

U.K. output of most chemical products is likely to be stepped up. The biggest gains are expected to be recorded by inorganic and organic chemicals, man-made fibers, and paints. On the other hand, production of cosmetics and pharmaceuticals may remain about on a par with 1986. Declines are likely in detergents, dyes, and plastics. Fertilizers will remain depressed.

"If chemical production generally increases in line with our forecasts, productivity will rise at a faster rate than it has for several years, and to a considerably greater extent in the U.K. than in its main competitor countries," Freeman notes. "We expect a further slight fall of some 1% in employment in the U.K. industry to bring the total to about 323,000."

Looking at the global macroeconomic picture, which, of course, affects the chemical industry, Alan Budd, director of economic forecasting at the London Business School, believes "that 1987 and 1988 will be years of comfortable growth and low inflation." He adds, "I am convinced that the potential benefits of the fall in oil prices have simply been postponed."

U.K. to lead chemicals growth in Europe



Among the 24 leading industrial countries that comprise the Organization of Economic Cooperation & Development (OECD), consumer spending was strong last year, but businesses were reluctant to expand output, Budd recalls. "Consumer demand, therefore, was met out of inventories, or by increased imports from outside OECD, particularly from countries like Taiwan and South Korea, which gained a considerable competitive advantage through exchange rate changes.

"The delay in seeing a strong recovery is hardly surprising," he adds, "when we realize that the world economy was subject to two major shocks in 1986—the sharp fall in oil prices and the dramatic fall in the dollar. Shocks are always upsetting, even if their long-term effects may be favorable. The best we can say is that 1986 ended rather more strongly than when it started."

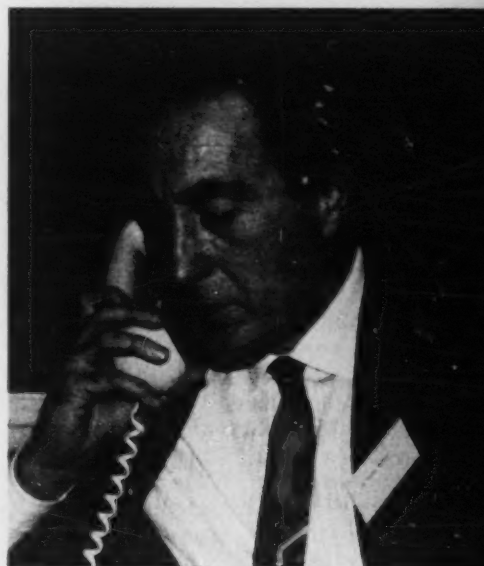
Contrary to the position taken by Freeman and his colleagues, Budd holds that the price of oil will fall back to \$15 a bbl, and then rise slowly in later years. Although admitting the outcome is highly uncertain, he doesn't expect that the Organization of Petroleum Exporting Countries (OPEC) will be able to sustain it at \$18 a bbl.

He foresees little change in fiscal and monetary policy in the key countries this year, which in turn would influence currency exchange rates. "Neither the European economies nor Japan will embark on expansionary policies, and there will

only be slow moves to deflationary policies in the U.S.," he thinks. "I also assume that threats of protectionism will not develop into a trade war."

Based on these and other assumptions, Budd expects that gross national product for OECD member countries on average will rise 4% this year over last compared with the 2.3% gain in 1986. Industrial production might advance a healthy 5%, whereas the increase in consumer prices, a measure of inflation, could fall back to 2%.

The encouraging outlook for the European chemical industry reflects to a degree improvement in the quality of its management, believes



Wamsley: management has improved

European capacity use rises as number of producers falls

	Capacity utilization, %	
	1988	1991
Ethylene	84%	71%
Polyethylene, low density and linear low density	89	62
Polyethylene, high density	84	64
Polypropylene	96	75
Polyvinyl chloride	82	64
Polystyrene	83	60

Source: Greenwell Montagu Securities

	Number of producers	
	1988	1990
Polyethylene, low density	15	21
Polyethylene, high density	14	20
Polypropylene	14	18
Polyvinyl chloride	16	24
Polystyrene	20	28

Stuart H. Wamsley, director in charge of international chemical research at Greenwell Montagu Securities, a London brokerage firm, who has been a vocal critic of the industry over the years. "The present generation of leadership is far more prepared to learn from the lessons of the past," he says.

"It is apparent that the more influential of today's chemical industry leaders not only recognize the opportunities and problems, but are seizing those opportunities to develop strategies for the future. Now there is much more awareness that only those companies that can maximize their talents, and develop and exploit the best market-led technology will emerge with strength. This, allied with the current phase of reshaping, divesting, and restructuring, could well ensure a far better future than seemed likely even just a year or two ago.

"Even in an era of slow growth, which I believe will continue for quite some time yet, the European chemical industry is alive and thriving. The prospects of survival, even of growth, are looking better now than for many a year," he believes.

The process of rationalization of the European chemical industry has made great strides. Since 1980, ethylene capacity has been cut back 25% to its present level of some 30 billion lb. The same has happened with low-density polyethylene (down 24% to 11.2 billion lb), high-density polyethylene (down 17% to 5.1 billion lb), polyvinyl chloride (down 12% to 1.6 billion lb), and polystyrene (down 7% to 4.9 billion lb). Meanwhile, the remaining plants are operating at higher levels of their design capacity.

"My view is that a further reduc-

tion in the number of producers now is a greater priority than the straight elimination of capacity," Wamsley says. "Hopefully this can take place in part by continuing withdrawal of the weak players as well as by farsighted measures such as the ICI/EniChem joint venture in PVC. While it is too early yet to total the disappearances in terms of tonnage, the end result is bound to be several really significant steps in the right direction.

"One point, though—fewer producers does not necessarily mean less capacity. Perhaps the best illustration of this is in PVC; there now are only 16 producers against 24 a few years ago. That's a drop of 33%, but only 12% of Europe's capacity has been shut down.

"Perhaps surprisingly, there now is increasing evidence to suggest that even in this disastrous product area, supply/demand balance is close. What I find increasingly encouraging is that there appears to be a continually widening list of product areas that are getting close to this supply/demand balance."

An obvious way of reducing the number of companies in a particular product area is by mergers and acquisitions. "We are not seeing too much of that in Europe these days," Wamsley observes. That is not to say that the Europeans are turning their backs on this form of restructuring. It's just that they have all decided that most important acquisitions have to be made in the U.S. They are cash-rich, and the decline of the dollar has made American assets look particularly cheap.

"With U.S. companies embroiled in their own attempts at restructuring, there has been no shortage of takeover candidates. Four [European]

companies alone—BASF, Hoechst, ICI, and Rhône-Poulenc—not counting another 20 or so that also have been active, have spent well [over] \$6 billion in the past two years in acquiring some famous American chemical names.

"Europe has bitten off some very big mouthfuls. I just hope the digestive system is in good working order. For while a number of these takeovers have good prospects, one or two of the latest ones smack of management being rushed into the game through fear of being left out. It will be interesting to assess results in a few years' time."

Wamsley foresees as "very probable" that Western Europe's share of base petrochemicals' production will decline in coming years in relation to other parts of the world. He notes that in 1980 Western Europe accounted for 34% of global petrochemical sales that totaled \$691 billion. Next in line was the U.S. with 23% of the total, followed by Eastern Europe with 19%, and Japan with 11%. Several countries made up the 13% balance. Looking ahead to 1995, he predicts a shift, with relative declines for Western Europe (to 25%), the U.S. (to 20%), and Eastern Europe (to 18%), while gains will be made by Japan (to 14%) and the "rest of the world" (to 23%).

"The threat of the new producers should not be underestimated," he warns. "In a number of product areas the quantities equate to, or exceed, the whole of the existing capacities of Western Europe. The conclusion I have to draw is that, given a shrinking share of production, Western Europe cannot justify having 12 of the world's top 20 companies, even if these companies diversify basic chemicals production drastically.

"The new sources of competition promise another unwelcome period of adjustment for European (and American) chemical producers. Having gone through two stages of painful restructuring and realignment in response to the pressures of the 1980s, this new challenge poses formidable problems, and the consequences will be substantial. Fewer European companies will be making their living from production of commodities." □

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FEBRUARY 16, 1987

CHEMICAL & ENGINEERING

NEWS



Borodin

The Russian composer-chemist died
100 years ago Page 28

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News of the Week

■ **Superconducting Super Collider is causing controversy in scientific community over cost and creating interest among states vying for site selection.** Page 4

■ **Worldwatch Institute's annual report deplores priorities of science in environmentally threatened world.** Page 5

■ **U.S. man-made fiber production increased in 1986; however, capacity was down.** Page 5

■ **EPA will share some authority with Office of Management & Budget in administering newly reauthorized Superfund.** Page 6

■ **NSF, in a push to improve science education for children, awards three grants totaling \$6.6 million.** Page 6

Cover: Portrait of Aleksandr Borodin, painted in 1870 by Elena Timofeevna Makovskaia, is in the State Central Museum of Musical Culture in Moscow

Letters 2

Concentrates

Business 7

Government 15

Science/Technology 23

The Departments

Books 36

ACS Comment 41

ACS News 42

Awards 47

New Products 49

Newsletters 64

Business

Chemical companies spent a record \$970 million in 1986 on pollution control, according to a Department of Commerce survey. Page 9

International Business

U.K. board of inquiry selects pressurized-water reactor for the next commercial nuclear power station. Page 10

Government

Reagan outlines his vision of science and technology in national policy in a comprehensive statement sent to Congress. Page 17

Funding increase of 11% is proposed for NSF chemical research in fiscal 1988 budget. Page 21

Override of President's veto of clean water bill has environmentalists cautiously optimistic about future of other environmental bills. Page 22

Technology

PPG biotechnology R&D agreement with Scripps is beginning to pay off in terms of basic research with potential commercial uses. Page 24

Improved glass interlayer process enables Monsanto to cut production costs and improve product quality. Page 25

Sedimentation field-flow fractionator that separates and characterizes particles and macromolecules is introduced by Du Pont. Page 26

Filtration/separation products are now a \$3.5 billion business in the U.S., spurred by electronics and biotechnology. Page 26



Special Report

February marks the 100th anniversary of the death of Russian composer and chemist Aleksandr Porfir'evich Borodin, whose works, both musical and chemical, are better known than his name. Page 28

NSF's chemical funding to rise 11% in 1988

Further details of President Reagan's fiscal 1988 budget proposal (C&EN, Jan. 19, page 21), including funding being sought for chemical programs at the Department of Energy and the National Science Foundation, became available late last month as the Office of Management & Budget and the various federal agencies released their budget support documents.

These documents show that at NSF, whose total proposed budget for fiscal 1988 is up almost 17% to \$1.9 billion, funding for the chemistry division is up 10% to \$103 million. That is only \$2 million more than was requested for the division in fiscal 1987. For fiscal 1987, Congress cut NSF's research and related activities budget request 5% or \$73 million. It told NSF to make the cuts wherever it pleased.

The chemistry division absorbed \$7.5 million of the budget shortfall.

That was achieved, according to budget documents, "by reducing support of core scientific research projects in all programs and deferring the plan to increase support for maintenance and operations associated with new shared instruments. Research activities underpinning biotechnology, collaborative research in areas such as materials chemistry, and research in computational chemistry will be supported at half the requested levels" in fiscal 1987.

The result of all this is a fiscal 1988 budget request for the chemistry division that is almost a duplicate of the fiscal 1987 request. The exceptions are chemical instrumentation, for which \$13 million was requested in fiscal 1987 and \$10 million is being requested in fiscal 1988, and special projects, for which the requests are \$7 million for 1987 and \$11 million for 1988. The special

projects office was set up last year to support collaborative research projects, as well as high-risk, innovative projects that don't really fit into the mainstream of current chemical research.

Of the \$9.2 million increase requested for the chemistry division, \$3.1 million would be devoted to strengthening the competitive base of U.S. colleges and universities in chemistry by increasing the support of student coworkers on research projects and continued support of Presidential Young Investigators. Another \$2.3 million would go to support "the chemistry of interfaces," \$2 million to continue the initiative in the chemistry of life processes, and \$1.9 million to increase the involvement of undergraduate students and faculty members from primarily undergraduate institutions in emerging areas of contemporary chemical research.

Funding for other NSF programs that provide support, in whole or in part, for chemical research would be up 11%, or \$15 million, to \$143 million in fiscal 1988 if Congress were to accept the budget request in toto.

DOE is asking for an 8% increase to \$124 million for the operating expenses of its chemical sciences research program in fiscal 1988. Of that amount \$88 million would be spent on research and the other \$36 million on facilities operation. According to DOE, this budget would provide support for 877 researchers, up from 847 in the current fiscal year, with university investigators accounting for slightly more than 30% of the total. In addition, another \$75 million would be allocated for support of the national laboratories, up from \$69 million in 1987.

DOE's fiscal 1988 budget request for materials science is \$170 million. That amount represents a 10% increase over current funding and would provide support for 1010 researchers, 12 more than in fiscal 1987, with university investigators accounting for 21% of the total. The materials science contribution toward support of the national laboratories would be \$110 million, an 8% rise over the current level.

Janice Long, Washington

NSF chemical program funding totals \$246 million

\$ Millions	1985*	1987*	1988*	% change 1987-88
Chemistry	\$102.7	\$ 93.5	\$ 85.8	10%
Physical chemistry	29.9	28.3	27.3	6
Organic & macromolecular chemistry	24.1	22.7	21.2	6
Inorganic, bioinorganic & organometallic chemistry	15.4	14.4	14.2	7
Analytical & surface chemistry	12.3	11.7	11.5	5
Special projects	11.0	6.4	3.6	72
Chemical instrumentation	10.0	10.0	8.0	0
Materials research	82.0	58.8	54.2	10
Laboratories	27.6	26.5	25.7	5
National facilities	11.3	10.5	9.9	8
Solid-state chemistry	9.6	8.6	8.3	12
Materials research groups	8.0	8.0	4.5	33
Instrumentation	5.3	5.0	5.8	6
Chemical, biochemical & thermal engineering	28.4	25.8	25.0	11
Thermal systems & engineering	8.9	8.0	8.0	11
Thermodynamics & transport phenomena	5.0	4.6	4.4	9
Process & reaction engineering	4.0	3.6	3.6	11
Multiphase & interfacial phenomena	3.6	3.3	3.1	9
Kinetics & catalysis engineering	3.5	3.1	3.0	13
Separation & purification processes	3.4	3.0	2.9	13
Biochemistry	16.6	14.9	14.2	11
Chemical oceanography	15.0	13.4	12.0	12
Atmospheric chemistry	10.5	8.6	6.9	22
Experimental & theoretical geochemistry	6.6	5.9	5.7	12
Volcanology & mantle geochemistry	4.2	3.7	3.5	14
TOTAL	\$246.0	\$222.2	\$207.3	11%

* Estimate, † Actual. Source: National Science Foundation

NOTE

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FEBRUARY 23, 1987

CHEMICAL & ENGINEERING

NEWS

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2/23/87 any earnings
4th-quarter 1986
page 14

The Rhine

Spills force chemical makers
to rethink pollution potential
Page 7

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News of the Week

■ **Bipartisan group of Congressmen pushes for an international effort to curb man-made emissions suspected of thinning Earth's protective ozone layer.** **Page 4**

■ **Forum on nuclear arms issues, sponsored by Soviet Academy of Sciences, is held in Moscow and attended by an international group of scientists, politicians, businessmen, and environmentalists.** **Page 5**

■ **Alvin Trivelpiece, now assistant secretary for energy research at DOE, is named to succeed William Carey as AAAS chief.** **Page 6**

■ **Henry Hass, noted researcher in the chlorination and nitration of paraffins, is dead at 85.** **Page 6**

Cover: Rhine River at Basel. Photo by C&EN's
James H. Krieger

Letters	2
Editor's Page	3
Concentrates	
Business	12
Government	22
Science/Technology	25
The Department	
Newsclips	52

Business

U.S. chemical firms' earnings increased sharply in fourth-quarter 1986 on only a modest rise in sales. **Page 14**

Du Pont sues against Allied-Signal charging infringement of Du Pont's polyester engineering resin patent seeks key Allied data. **Page 18**

International Business

Canadian chemical producers' profits jumped in 1986, despite relatively weak fourth quarter. **Page 19**

Global man-made fiber output shifts away from U.S., Japan, and West European countries. **Page 20**

Government

Nuclear reactor at Hanford, Wash., which shares some features with Chernobyl model, will keep operating with safety alterations. **Page 23**

Chemical Warfare Review Commission is accused by GAO of violating established administrative procedures. **Page 24**

EPA receives first premanufacture notification from a company seeking to field test genetically engineered microorganisms. **Page 24**

Education

Science and technology in society programs and an interdisciplinary approach are focus of effort to develop technological literacy. **Page 26**

Science

Global decrease in forests and biological species is a critical issue, warns AAAS keynote speaker Peter Raven. **Page 28**

ACS News

Region V director candidates I. Dwaine Eubanks, Louis J. Sacco Jr., and John G. Verkade discuss their views on ACS. **Page 30**



News Focus

In the aftermath of the fire-related spill of toxic chemicals and other releases into the Rhine, chemical firms and governments alike review environmental regulations. **Page 7**

Chemical Earnings Rise Sharply In Fourth Quarter

William J. Storck, C&EN New York

Earnings for major U.S. chemical firms increased sharply in the fourth quarter of 1986, spurred by lower raw material costs, continued efficiency improvements, and better foreign trade conditions. Major diversified companies that produce chemicals also posted improved earnings, but oil and gas producers with chemical operations registered lower earnings, because of poor oil pricing during the period.

Although the chemical business

in terms of demand and pricing is still far from robust, most chemical producers have introduced process efficiencies, cut staff and other costs, and taken advantage of lower raw material costs to such an extent that breakeven points have been lowered to levels where there is tremendous earnings leverage. Thus, even a small rise in capacity utilization can now result in a large rise in profits.

Also, chemical companies are finding that demand is coming back, even in the basic building-block chemicals such as ethylene and pro-

pylene, spurred by increased domestic demand and improving trade conditions. However, companies may have milked domestic demand about as much as they can for the immediate future. Industry analysts and economists say that demand for chemicals from the automotive area (one of three large chemical markets—the others are housing and agriculture) may not improve much in 1987. They feel that the tax reform that took effect Jan. 1, which prevents deductions of interest charges on consumer debt and also

Chemical industry leaders for the fourth quarter . . .

Sales		
Rank 1986	\$ Millions	Rank 1985
1 Dow Chemical	\$2862.0	1
2 Union Carbide	1600.0	3
3 Monsanto	1570.0	2
4 PPG Industries	1200.0	4
5 American Cyanamid	949.6	5
6 Celanese	700.0	6
7 Hercules	640.5	7
8 National Distillers	541.3	10
9 Air Products	533.7	9
10 Rohm & Haas	468.6	8

Earnings		
	\$ Millions	Rank 1985
Dow Chemical	\$169.0	nr
PPG Industries	73.0	1
Celanese	57.0	2
American Cyanamid	52.1	13
Hercules	47.4	5
Ethyl	45.8	3
Air Products	38.9	4
Rohm & Haas	35.8	7
National Distillers	29.5	10
Monsanto	23.0	29

Profitability		
	Earnings as % of sales	Rank 1985
Ethyl	11.7%	3
International Flavors	11.6	1
Freeport-McMoRan	11.2	2
Celanese	8.1	8
Nalco Chemical	7.9	4
Loctite	7.6	5
Rohm & Haas	7.6	15
Hercules	7.4	10
Air Products	7.3	6
Aristech	6.3	19
Cabot	6.3	7

. . . and for full-year 1986

Sales		
Rank 1986	\$ Millions	Rank 1985
1 Dow Chemical	\$11,405.0	1
2 Monsanto	6,879.0	2
3 Union Carbide	6,300.0	3
4 PPG Industries	4,700.0	4
5 American Cyanamid	3,815.9	5
6 Celanese	2,891.0	6
7 Hercules	2,615.0	7
8 Rohm & Haas	2,066.9	8
9 Air Products	2,040.0	9
10 National Distillers	1,729.6	11

Earnings		
	\$ Millions	Rank 1985
Dow Chemical	\$741.0	nr
Monsanto	365.0	2
PPG Industries	316.0	1
Celanese	213.0	3
Hercules	206.4	5
American Cyanamid	202.5	8
Ethyl	177.7	6
Rohm & Haas	169.3	7
Air Products	144.0	4
Union Carbide	130.0	9

Profitability		
	Earnings as % of sales	Rank 1985
International Flavors	13.8%	1
Ethyl	11.3	4
Freeport-McMoRan	10.4	2
Loctite	8.7	5
Rohm & Haas	8.2	9
Hercules	7.9	11
Nalco Chemical	7.9	3
Celanese	7.4	10
Air Products	7.1	6
PPG Industries	6.7	8

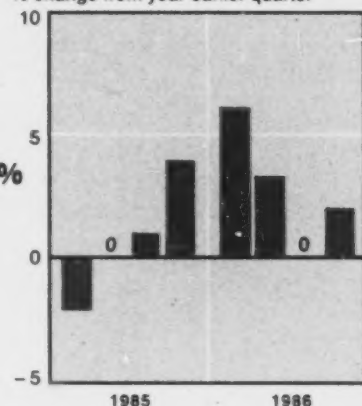
Note: Based on 30 companies listed on page 16. nr = not ranked.

Chemical industry 1986 fourth-quarter results

- Sales increased slightly
- Earnings soared
- Profit margins rose to 4.9%
- Production was up 5%
- Prices continued to fall

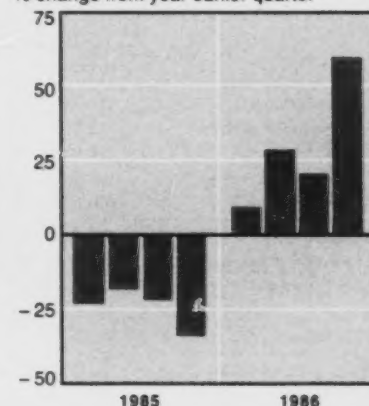
Sales

% change from year-earlier quarter



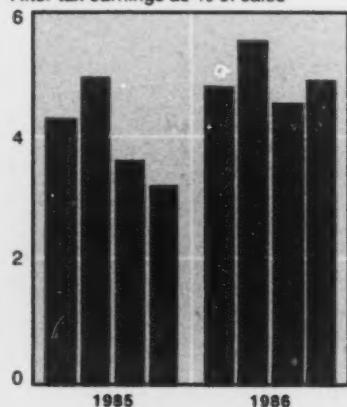
Earnings

% change from year-earlier quarter



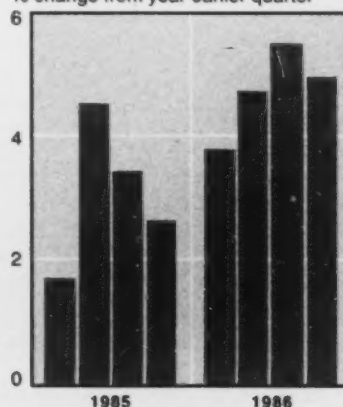
Profit margins

After-tax earnings as % of sales



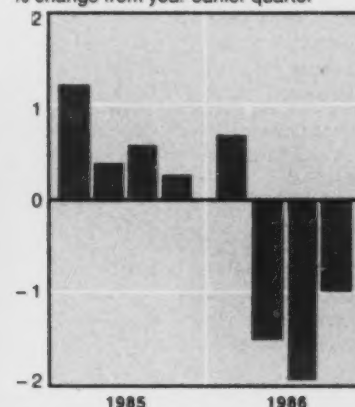
Production

% change from year-earlier quarter



Prices

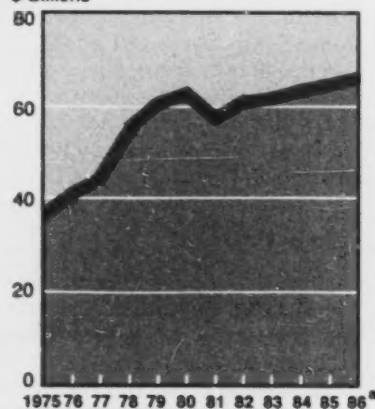
% change from year-earlier quarter



Sales in 1986 were up slightly while earnings climbed almost 25%, driving profit margins back up to 5%

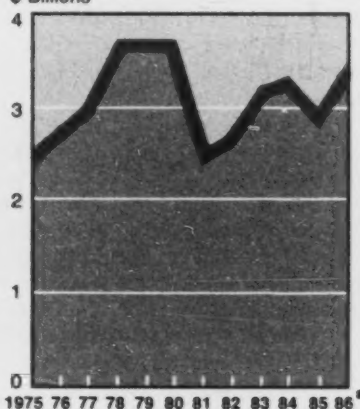
Annual sales

\$ Billions



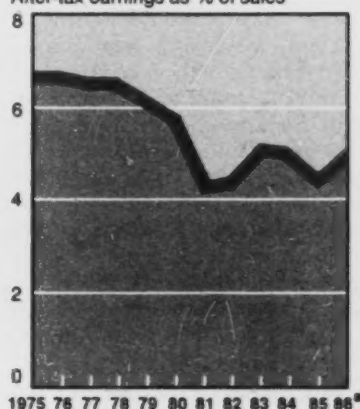
Annual earnings

\$ Billions



Annual profit margins

After-tax earnings as % of sales



Note: All sales, earnings, and profit-margin data are based on combined results of 30 companies listed on page 18. ■ C&EN estimates.

Earnings, profit margins increase at most chemical companies

	FOURTH-QUARTER 1986						FULL-YEAR 1986					
	Sales	Earnings ^a	Change from 1985		Profit Margin ^b		Sales	Earnings ^a	Change from 1985		Profit Margin ^b	
	(\$ millions)		Sales	Earnings	1986	1985	(\$ millions)		Sales	Earnings ^a	1986	1985
Air Products ^c	\$ 533.7	\$ 38.9	15%	7%	7.3%	7.8%	\$ 2,040.0	\$ 144.0	10%	-3%	7.1%	7.9%
American Cyanamid ^c	949.6	52.1	7	396	5.5	1.2	3,815.9	202.5	8	68	5.3	3.4
Aristech	176.0	11.1	-7	98	6.3	3.0	750.8	47.6	-5	132	6.3	2.6
Cabot	300.8	18.8	-16	-31	6.3	7.6	1,253.3	56.5	-10	-19	4.5	5.0
Celanese ^c	700.0	57.0	-8	14	8.1	6.6	2,891.0	213.0	-5	20	7.4	5.8
Chemed	92.8	3.8	14	6	4.1	4.4	359.5	16.6	10	1	4.6	5.0
Crompton & Knowles	53.8	2.2	13	-1	4.0	4.6	213.2	8.9	9	14	4.2	4.0
Dow Chemical ^{c,d}	2,862.0	169.0	-2	def	5.9	def	11,405.0	741.0	-1	1178	6.5	0.5
Ethyl ^c	391.0	45.8	3	21	11.7	10.0	1,579.3	177.7	2	36	11.3	8.9
First Mississippi	62.3	0.1	-16	-97	0.1	4.2	247.3	4.8	-12	-62	1.9	4.4
Freeport-McMoran	157.1	17.6	1	8	11.2	10.5	615.2	63.8	-15	-21	10.4	11.1
H. B. Fuller	139.9	5.2	20	22	3.7	3.6	528.6	18.9	15	42	3.6	2.9
B. F. Goodrich ^c	na	na	na	na	na	def	na	na	na	na	na	def
W. R. Grace ^c	na	na	na	na	na	2.2	na	na	na	na	na	2.0
Hercules ^c	640.5	47.4	1	53	7.4	4.9	2,615.0	206.4	1	45	7.9	5.5
International Flavors	145.7	17.0	19	16	11.6	12.0	620.7	85.7	24	23	13.8	13.9
International Minerals ^c	380.7	-8.9	76	def	def	0.6	1,571.6	5.8	34	-86	0.4	3.7
Loctite	81.0	6.4	24	14	7.8	8.5	292.4	25.3	22	32	8.7	8.0
Lubrizol	na	na	na	na	na	5.6	na	na	na	na	na	6.7
Monsanto ^c	1,570.0	23.0	-11	def	1.5	def	6,879.0	365.0	2	71	5.3	3.2
Nalco Chemical	189.0	14.9	2	-14	7.9	9.4	736.1	58.0	8	-13	7.9	9.8
National Distillers ^c	541.3	29.5	17	93	5.4	3.3	1,729.6	55.1	7	-11	3.2	3.8
Olin ^c	408.0	8.2	4	-2	2.0	2.1	1,710.0	75.2	-2	89	4.4	2.3
Pennwalt	279.0	12.6	7	101	4.5	2.4	1,107.6	51.9	8	363	4.7	1.1
Petrolite	65.9	3.5	-18	-2	5.4	4.5	280.0	17.5	-9	-22	6.2	7.3
PPG Industries ^c	1,200.0	73.0	9	24	6.1	5.4	4,700.0	316.0	9	4	6.7	7.0
Reichhold Chemicals	164.7	0.9	-15	def	0.5	def	765.6	15.9	-7	def	2.1	def
Rohm & Haas ^c	468.6	35.8	0	80	7.6	4.2	2,066.9	169.3	1	24	8.2	6.6
Union Carbide ^c	1,600.0	14.0	0	180	0.9	0.3	6,300.0	130.0	-2	9	2.1	1.9
Witco	326.1	16.5	-6	9	5.1	4.3	1,355.0	65.2	-6	15	4.8	3.9
Total 12 largest firms ^a	\$ 9,383.4	\$ 415.8	3%	69%	4.4%	2.7%	\$ 37,898.3	\$ 2060.1	4%	26%	5.4%	4.5%
Smaller 14 firms	\$ 2,234.0	\$ 130.4	-2%	15%	5.8%	5.0%	\$ 9,125.2	\$ 536.6	-1%	15%	5.9%	5.1%
GRAND TOTAL ^a	\$ 11,617.4	\$ 546.2	2%	52%	4.7%	3.2%	\$ 47,023.4	\$ 2596.7	3%	23%	5.5%	4.6%

a After-tax earnings from continuing operations excluding significant nonrecurring and extraordinary items. b After-tax earnings as a percentage of sales. c One of largest 15 companies. d Includes significant nonrecurring item in fourth-quarter and full-year 1985. e Totals for larger companies and for total 26 companies exclude Dow, which, because of included nonrecurring items, would make years not comparable. na = not available. def = deficit.

the deduction of sales tax on big-ticket items such as automobiles, will slow auto buying at least through the first half of this year. Also, sales incentives offered by U.S. auto makers in the latter part of 1986 encouraged some auto buyers, who normally would have waited until 1987, to make their purchases in 1986 to take advantage of cut-rate financing and other deals.

The housing market also is forecast to be soft in 1987, as some parts of the country are overbuilt in terms of apartments and single family houses. And the tax reform measure has removed incentives from speculative building.

Agriculture too is a problem,

domestically as well as worldwide. Supply of agricultural products has far outstripped demand in recent years hurting all agricultural chemicals.

This leaves foreign trade to take up some of the slack in demand this year, and if the latter part of 1986 is any indication, it is trying. Finally, helped by the weaker dollar, chemical trade in 1986 rebounded from a five-year slide, with the chemical trade surplus increasing 7.5% over the previous year (C&EN, Feb. 9, page 6). The weaker dollar, besides making domestically produced chemicals cheaper abroad and foreign chemicals more expensive here, will raise the price of imported

finished goods, thus making it more difficult for them to compete with domestically produced goods. This, in turn, may increase chemical markets within the U.S. somewhat.

The improvement in foreign business is apparent in comments made by company executives. For instance, Du Pont chairman and chief executive officer Richard E. Heckert says, "Most of our chemical and specialty products businesses posted strong earnings, reflecting an improved cost structure and strength overseas."

The improvement in efficiency and foreign trade was what led to a tremendous increase in earnings in the fourth quarter. It certainly wasn't

Profits dropped for major oil companies but rose for most diversified firms

	% chemical sales	FOURTH-QUARTER 1986						FULL-YEAR 1986					
		Sales	Earnings ^a	Change from 1985		Profit margin ^b		Sales	Earnings ^a	Change from 1985		Profit margin ^b	
		(\$ millions)		Sales	Earnings	1986	1985	(\$ millions)		Sales	Earnings	1986	1985
OIL AND GAS COMPANIES													
American Petrofina	15%	\$ 527.9	\$ 5.0	-20%	def	1.0%	def	\$ 2,020.9	\$ -24.6	-17%	def	def	def
Amoco	14	4,800.0	165.0	-35	-58%	3.4	5.3%	20,200.0	973.0	-30	-50%	4.8%	6.8%
Ashland	18	1,600.0	27.0	-20	-46	1.7	2.5	6,900.0	191.0	-15	12	2.8	2.1
Atlantic Richfield	17	3,724.0	64.0	-32	-55	1.7	2.6	15,092.0	615.0	-33	85	4.1	1.5
Chevron	6	5,900.0	230.0	-45	-62	3.9	5.6	27,600.0	1,030.0	-39	-33	3.7	3.4
Kerr-McGee	14	588.8	8.8	-35	-68	1.5	3.1	2,534.6	23.3	-24	-83	0.9	4.1
Mobil	5	12,000.0	201.0	-27	-53	1.7	1.4	49,400.0	1,555.0	-18	0	3.1	2.6
Phillips Petroleum	15	2,380.0	11.0	-39	-91	0.5	3.1	10,020.0	110.0	-37	-76	1.1	2.8
Shell Oil	17	4,512.0	192.0	-18	-65	4.3	9.9	17,353.0	821.0	-15	-47	4.7	7.5
Standard Oil	4	2,264.0	67.0	-39	-82	3.0	10.3	10,022.0	499.0	-27	-66	5.0	10.6
Sun	24	2,210.0	54.0	-50	-60	2.4	3.1	10,440.0	383.0	-31	-27	3.7	3.5
Texaco	3	7,800.0	-59.0	-38	def	def	2.6	32,600.0	616.0	-31	-51	1.9	2.6
Unocal (Union Oil)	11	2,060.0	49.2	-29	def	2.4	def	8,350.0	90.8	-28	-70	1.1	2.6
DIVERSIFIED MANUFACTURERS													
Allied-Signal	24	3,035.0	69.0	16	11	2.3	2.4	11,794.0	559.0	29	32	4.7	4.7
Borden	33	1,356.4	68.8	9	23	5.1	4.5	5,002.1	223.3	6	15	4.5	4.1
Borg-Warner	28	913.0	52.5	6	-16	5.8	7.3	3,623.4	206.1	9	15	5.7	5.4
Du Pont	44	6,677.0	335.0	-12	-11	5.0	4.9	27,148.0	1,538.0	-8	38	5.7	3.8
Eli Lilly	22	969.4	124.3	19	0	12.8	15.2	3,720.4	558.2	14	8	15.0	15.8
Engelhard	26	702.2	14.3	4	28	2.0	1.6	2,289.5	53.3	1	25	2.3	1.9
FMC	43	778.1	50.8	-9	30	6.5	4.6	3,002.0	152.5	-8	-22	5.1	6.0
GAF	50	182.2	19.0	5	56	10.5	7.0	753.8	80.7	3	49	10.7	7.4
General Electric	8	12,270.0	730.0	41	14	5.9	7.3	35,210.0	2,492.0	24	9	7.1	8.0
Kaiser Aluminum	13	544.6	-38.9	6	def	def	def	2,221.5	-54.4	10	def	def	def
Koppers	44	329.7	15.4	-6	def	4.7	def	1,396.4	63.2	0	def	4.5	def
Merck	13	1,149.1	171.8	20	28	15.0	14.0	4,128.9	675.7	16	25	16.4	15.2
3M	15	2,112.0	185.0	8	25	8.8	7.5	8,602.0	779.0	10	17	9.1	8.5
Pfizer	10	1,162.9	158.4	10	14	13.6	13.2	4,476.0	660.0	11	14	14.7	14.4
Tyler	41	237.0	0.1	8	-81	0.1	0.3	961.4	11.9	5	-22	1.2	1.7
Vulcan Materials	27	237.0	15.6	-1	9	6.6	6.0	957.8	93.2	-1	17	9.7	8.2

a Earnings from continuing operations excluding significant extraordinary items. b After-tax earnings as a percentage of sales. def = deficit.

production and prices. Chemical production in the fourth quarter was up only about 5% over the same period in 1985 and prices in the period for chemicals and allied products were actually down slightly from the same three-month period the year before.

Thus, sales dollar volume in the fourth quarter was nothing to write home about. For 26 of the 30 major chemical firms that C&EN normally surveys, combined sales in the fourth quarter increased only 2% to \$11.6 billion. W. R. Grace, B. F. Goodrich, and Lubrizol did not report in time to be included in the total. Dow Chemical is not included because its fourth-quarter 1985

earnings included a massive non-recurring charge that cannot be factored out. Thus, if Dow were included, the comparisons would be meaningless.

However, in spite of the only 2% rise in chemical sales for the firms, the 26 companies reported combined earnings of \$546 million, up a significant 52% from the same period the year before. As a result, profitability for the companies improved considerably. Profit margins (after-tax earnings as a percentage of sales) for the group averaged 4.7% in the fourth quarter of 1986, compared with just 3.2% in the same period the year before.

For the quarter, the larger firms

outperformed the smaller in growth as they have in recent quarters. For the 12 larger companies (excluding Dow, Grace, and Goodrich), sales increased 3% to a combined \$9.38 billion. But earnings were up a whopping 69% to \$416 million. For the 14 smaller companies (Lubrizol not included), sales were down 2% to \$2.23 billion, and earnings increased just 15% to \$130 million.

However, the smaller companies continue their dominance in profitability. Profit margins at the smaller companies showed a weighted average in the fourth quarter of 5.8%, up from 5.0% in the same period the year before. The average profit margin for the larger firms

in the fourth quarter was 4.4%, up from 2.7% in the same period of 1985.

For the full year, the story was much the same. For the 26 companies, combined sales increased 3% from 1985 to \$47.0 billion. Earnings increased 23% to a total of \$2.60 billion.

For the 12 larger firms, combined sales rose 4% to \$37.9 billion, and earnings increased 26% to \$2.06 billion. For the 14 smaller companies, combined sales fell 1% to \$9.13 billion, but earnings rose 15% to \$537 million.

Profit margins for the full group averaged 5.5% for 1986, up from 4.6% in 1985. For the larger companies margins averaged 5.4%, up from 4.5% the year before. For the smaller companies profit margins averaged 5.9% for all of 1986, up from 5.1% in 1985.

Apart from the companies that moved out of the deficit column in the fourth quarter, the largest percentage increases for 1986 were posted by American Cyanamid, Union Carbide, and Pennwalt, all of which more than doubled earnings from the previous year. Cyanamid had the biggest increase, with earnings rising 396% from 1985 to \$52.1 million on a sales gain of 7%. Chairman George J. Sella Jr. says the increased earnings are the result of new product introductions, continuing cost reduction programs, and increased volumes in overseas markets, as well as the favorable impact of the weaker dollar.

Carbide reported an increase in earnings on continuing operations of 180% over 1985 to \$14 million on flat sales of \$1.60 billion. And Pennwalt's earnings rose 101% to \$12.6 million on a sales rise of 7% to \$279 million. Pennwalt chairman Edwin E. Tuttle says, "Chemical earnings were especially strong, increasing 80% over 1985 levels, with gains by the organic and fluorochemicals divisions being particularly impressive. This performance was the result of higher sales volume as well as improved plant operations."

Another company, one of the smaller 14 firms, almost doubling its earnings, is new to C&EN's list and a newly publicly traded company. Aristech, the former chemi-

cal arm of USX Corp., which went public in December, showed an earnings gain in the fourth quarter of 98% over the same period the year before to \$11.1 million on a 7% decline in sales to \$176.0 million.

Chemical companies were not the only firms to register good chemical results. Despite a drop in overall earnings, oil companies' chemical operations exhibited vastly improved results in most cases. For Shell Oil, earnings from chemical products for the fourth quarter increased 327% from fourth-quarter 1985 to \$141 million. For the full year, Shell's chemical earnings were up 256% from 1985 to \$342 million.

At Chevron, chemical operations contributed \$31.0 million in the fourth quarter, compared with a \$30 million loss in fourth-quarter 1985.

And for full-year 1986, the company posted chemical earnings of \$108 million, up from total 1985 chemical earnings of only \$3.0 million.

Texaco also came out of a deficit in the fourth quarter of 1985, showing petrochemical earnings in fourth-quarter 1986 of \$17 million, compared with a \$2.0 million loss in the year-earlier quarter. For full-year 1986, Texaco's petrochemical earnings were \$56 million, compared with just \$5 million for 1985.

Excluding nonrecurring items, Atlantic Richfield's chemical earnings for the fourth quarter last year increased to \$52.0 million from \$30 million in the fourth quarter of 1985. For 1986, excluding nonrecurring items, the company's chemical profits totaled \$132 million, up from \$107 million the year before. □

Du Pont suit seeks key Allied polyester data

Earlier this year, Du Pont filed a suit against Allied-Signal charging that Allied's Petra thermoplastic polyester resin infringed on Du Pont's patent covering Rynite polyester engineering resin. Du Pont is seeking an injunction to halt the production of Petra. The success of the suit may ultimately depend on Allied's use of certain plasticizers and lubricants in the manufacture of its engineering resin.

The suit, filed in U.S. District Court in Wilmington, Del., centers on Patent No. 4,352,904 issued to Du Pont on Oct. 5, 1982. That patent describes the use of polyethylene terephthalate (PET) resins to mold a number of high-gloss engineered components for automotive, aerospace, electrical, and electronic end uses at lower mold temperatures than previously possible.

Documents that Du Pont's legal department filed with the district court do not disclose the exact nature of Allied's alleged infringement on Du Pont's patent. However, the suit requests that Allied submit information concerning key chemical components and processes that may show where Du Pont believes its patent was violated.

Specifically, Du Pont wants to know how Allied may use certain plasticizers and lubricants in form-

ing its PET engineering resin. These plasticizers and lubricants are sodium dimerate, ethylene/acrylic acid copolymer, butyl benzyl phthalate, and any aromatic sulfonamide.

Du Pont also wants to know if any sodium salt is used either during the manufacture of the resins or in the use of the resins for molding. It also seeks specific information on heat requirement and process temperatures required either for resin formulation or molding.

In its suit, Du Pont claims that Allied's Petra resin has captured 10% of the polyester molding resins market. Though Du Pont does not say how large it believes the market to be, industry sources say that Du Pont has 25 million lb of PET thermoplastic resin capacity to Allied's 5 million lb. Mobay Chemical, which is not involved in the Du Pont suit, has a capacity of 20 million lb for its Petlon PET resin, sources say.

According to Lawrence H. Gillespie Jr., a Du Pont polymer products department director, "Du Pont has invested millions of dollars in this technology." To date, he says, Du Pont has commercialized 20 different types of Rynite. "We intend to protect this investment under the rights granted us by the U.S. patent system."

Marc Reisch, New York

Earnings of Canadian Chemical Firms Improved Last Year

Relatively weak fourth quarter for four large companies fails to halt fatter profits on small increases in sales

For most Canadian chemical producers, last year was a good one as far as the bottom line is concerned. That, at least, is the indication based on results of the four major publicly traded Canadian chemical companies tracked by C&EN (C-I-L, Celanese Canada, Du Pont Canada, and Union Carbide Canada). Average net earnings of these four companies jumped a welcome 35% in 1986, even though their combined sales inched ahead only 2.8%.

From other sectors of the Canadian chemical industry, the message seems to be the same: lower or only slightly higher sales, but a big improvement in profit. At Esso Chemical Canada, for instance, 1986 sales

were down about 4%, but net earnings increased almost sixfold.

Polysar, the Sarnia-based elastomer and petrochemical giant, also fits the mold. Its sales rose 11% last year to \$1.44 billion (\$1.00 = 1.393 Canadian dollars, 1986 average). Earnings, however, rose from virtually nothing in 1985 to \$20 million last year.

The problem with "average" results, however, is that some companies usually do better and some companies worse. Thus, officials at C-I-L, whose net income slid 49%, may not think that 1986 was as good a year as, say, those at Du Pont Canada. That company chalked up a hefty 193% earnings gain last year.

Among Canadian chemical companies last year, earnings performance seemed to depend to a large extent on their product lines. A weak agricultural market hurt companies that rely heavily on fertilizer and agricultural chemicals. In the oil patch, sales of oil field chemicals were off. Losses from methanol operations kept the net income of

Celanese Canada lower than it might have been.

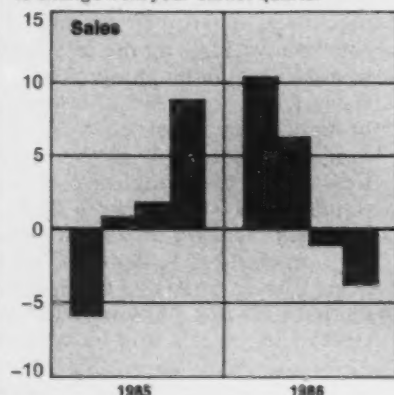
On the other hand, profits were surprisingly strong in some chemical sectors, as demand perked up and prices rose. Plastics, fibers, and some industrial chemicals were among the better-performing segments of the Canadian chemical industry last year.

Another factor is that cost-cutting programs over the past few years really have produced some Canadian chemical companies that are "leaner and meaner." J. E. Newall, president of Du Pont Canada, attributes his company's improved profit margins to lower costs and slightly higher prices in many product areas, particularly plastics and fibers. "Improved" profit margins is an understatement. Earnings rose 193% to \$43.4 million, as sales improved only 4.8% to \$890 million. As a result, Du Pont Canada's profit margin (earnings as a percent of sales) rose to 4.9% last year from 1.7% in 1985.

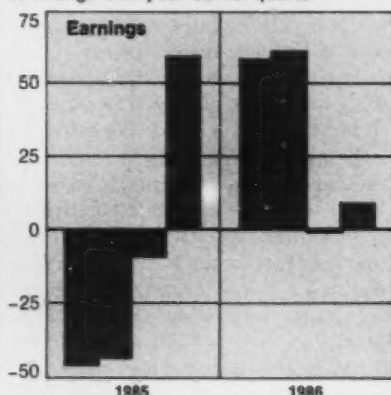
For Du Pont Canada, the new and

Canadian chemical sales weaken, but profits rebound in fourth quarter

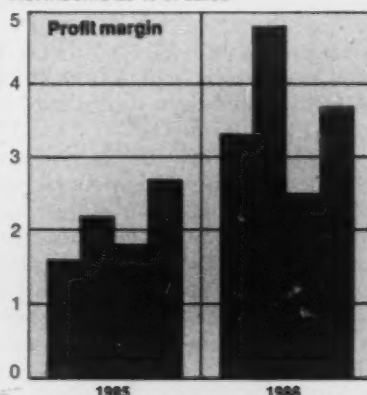
% change from year-earlier quarter*



% change from year-earlier quarter*



Net income as % of sales*



* Based on combined Canadian-currency results of C-I-L, Celanese Canada, Du Pont Canada, and Union Carbide Canada.

Good year for Canadian firms ends on weak fourth quarter

\$ Millions ^a	Net sales	FOURTH-QUARTER 1986				Profit margin ^d	
		Change from 1985 ^b	Net income ^c	Change from 1985 ^b	1986	1985	
C-I-L	\$ 207.6	-7.9%	\$ 2.9	-20.0%	1.4%	1.6%	
Celanese Canada	65.8	-5.5	3.8	1.9	5.8	5.4	
Du Pont Canada	216.2	1.2	10.4	107.1	4.8	2.4	
Union Carbide Canada	64.9	-3.2	3.5	-46.2	5.4	9.7	
TOTAL	\$ 554.5	-3.7%	\$20.6	9.1%	3.7%	3.3%	

FULL-YEAR 1986							
C-I-L	\$ 923.6	2.1%	\$14.4	-48.7%	1.6%	3.1%	
Celanese Canada	247.2	2.3	13.5	49.2	5.5	3.7	
Du Pont Canada	889.9	4.8	43.4	193.2	4.9	1.7	
Union Carbide Canada	257.0	-0.5	14.5	26.3	5.6	4.4	
TOTAL	\$2317.7	2.8%	\$85.8	35.4%	3.7%	2.8%	

^a \$1.00 = 1.393 Canadian dollars. ^b Based on Canadian currency. ^c Based on continuous operations and excluding extraordinary items. ^d Net income as percentage of sales.

resale housing market was particularly strong in 1986, as were its automotive and industrial markets. As a result, most of the company's fibers products, as well as engineering plastics, specialty packaging film, and hydrogen peroxide, chalked up healthy gains.

Newall conceded, however, that the resource, agricultural, and electronics sectors of the Canadian economy were "difficult" for Du Pont Canada last year. Weakness in these sectors kept sales of crop protection chemicals about even with 1985 and pushed lower the volume of explosives, polyethylene pipe, and electronic connectors.

At C-I-L, net earnings were down sharply last year, even though sales managed to inch upward 2% to \$924 million. Company earnings, at \$14.4 million, were down a troublesome 49%, and the primary culprit was the agricultural market. Lower ammonia prices, reduced fertilizer demand, and lower income from crop protection chemicals combined to hurt C-I-L's bottom line.

In addition, profit for its specialty chemicals and services operation fell almost \$3 million, reflecting lower sales to gas and oil industry customers. Explosives sales also were down, but both volume and profits increased for such products as plastic films, polymers, caustic soda, and chlorine.

Celanese Canada managed to increase its net income 49%, to \$13.5 million, even though sales increased

only 2.3% to \$247 million. The company's earnings strength came from textiles, chemicals, and industrial products. Cellulosics were particularly strong.

But the company's profit picture would have been even better had it not been for its methanol operation. Celanese has a 2100 metric-ton-per-day methanol plant in Al-

berta. But methanol supply far outstrips demand. Executive vice president Paul H. Williams says that methanol continues to suffer from depressed prices worldwide. Losses on methanol, he adds, more than offset Celanese Canada's profits from other chemical product lines.

Sales at Union Carbide Canada remained virtually flat last year at \$257 million, but net income rose 26% to \$14.5 million. These figures reflect sales and income from plastics, chemicals, industrial gases, and carbon operations.

An extraordinary gain of about \$22 million, coupled with a small loss from discontinued operations, brought Carbide Canada's final net income for the year up to \$34 million. The major "extraordinary item" concerned the sale of the company's consumer product, food casings, and carbon brush businesses during the year.

For most Canadian chemical firms, performance in the fourth quarter was not so good as for the entire year. This may, or may not, be a harbinger of things to come in 1987.

Earl Anderson, New York

Man-made fiber output continues shift from U.S.

Countries other than the U.S., Japan, and those of Western Europe continue to take an ever increasing share of the global output of man-made fibers. That is the conclusion from the latest review compiled by Enka, the fiber-making arm of Akzo of the Netherlands.

In the case of man-made fibers, which include those such as rayon made by chemically modifying natural cellulose, these "other" countries have come a long way fast since their collective output first exceeded that of the U.S. and Western Europe as recently as 1974. Last year, they accounted for almost 49% (some 17.9 billion lb) of the 36.8 billion lb world total. They will pass the 50% mark before long if they maintain the 6.4%-per-year annual growth rate that they have attained since 1980.

Over the same time span, U.S. production has undergone an average annual decline of 1.2% to last year's almost 8 billion lb level (22%

of the world total). The slowdown in Japan was half that at 0.6% a year to bring its 1986 output to 3.9 billion lb, 10% of the total. Western Europe, on the other hand, achieved a modest 1.4%-a-year growth to 7.1 billion lb, 19% of the total.

Looking at synthetic fibers, mainly the polyamides (nylons), polyesters, and acrylics, the 1980 to 1986 year-to-year growth among the countries making up the rest of the world is even more pronounced. For them, the average of 8.8% annually brought them to last year's 13.9 billion lb, almost 47% of the world total output of synthetics. U.S. output declined 0.9% yearly to slightly less than 7 billion lb, 23% of world total production. In contrast, annual gains were registered by Japan—a modest 0.2% to 3.1 billion lb in 1986 (10% of the total)—and by Western Europe—a more respectable 3.3% to 5.8 billion lb (20% of global output).

Since 1973, when cellulosic fibers achieved the peak of their global

Production of man-made fibers continues to grow . . .

Billions of lb (% change from previous year)	1986	1985	1984	1983	1982	1980
U.S.	7.97 (2.6%)	7.75 (-2.1%)	7.92 (-1.5%)	8.04 (15.5%)	6.96 (-19.4%)	8.58 (-6.7%)
Western Europe	7.11 (-1.8)	7.24 (-2.3)	7.08 (5.2)	6.73 (5.8)	6.36 (-7.3)	6.55 (-9.5)
Japan	3.85 (-3.3)	3.98 (0.0)	3.98 (2.6)	3.88 (1.6)	3.82 (-2.6)	3.98 (-1.0)
Other	17.85 (7.0)	16.69 (7.2)	15.57 (12.3)	13.87 (6.4)	13.03 (1.1)	12.31 (6.8)
TOTAL	36.78 (3.1%)	35.66 (3.2%)	34.55 (6.2%)	32.52 (7.8%)	30.17 (-6.6%)	31.42 (-1.8%)

. . . reflecting rise in synthetics output

U.S.	6.96 (2.2%)	6.81 (-1.3%)	6.90 (-1.4%)	7.00 (17.3%)	5.97 (-19.8%)	7.37 (-6.7%)
Western Europe	5.78 (-1.2)	5.85 (5.6)	5.54 (6.5)	5.20 (8.3)	4.80 (-7.0)	4.77 (-10.0)
Japan	3.06 (-2.2)	3.13 (2.3)	3.06 (3.7)	2.95 (1.4)	2.91 (-2.0)	3.03 (-1.0)
Other	13.69 (8.5)	12.80 (8.8)	11.76 (15.1)	10.22 (9.5)	9.33 (3.4)	8.37 (9.4)
TOTAL	29.69 (3.8%)	28.59 (4.9%)	27.26 (7.4%)	25.37 (10.3%)	23.01 (-6.5%)	23.54 (-1.5%)

Source: Enka

output of 8.5 billion lb, production has continued to decline. Last year's 7.1 billion lb was about on a par with 1985's, accounting for 19% of the total man-mades. Synthetics, on the other hand, achieved an all-time high of 29.7 billion lb, nearly 4% better than in 1985.

Among the synthetics, polyester fibers accounted for half the total (15.0 billion lb) for the second year running. Indeed, the relative proportion of all the fiber types remained unchanged, 26% (7.6 billion lb) for the polyamides, 18% (5.3 billion lb) for the acrylics, and 6% (1.7 billion lb) for the others—fibers made from polypropylene, polyvinyl chloride, elastomers, and the like.

Between 1980 and 1986, production of synthetic fibers advanced almost 4% a year on average. The pace of polyester fiber growth was highest, 5.1%, followed by acrylics, 3.0%, and polyamides, 1.4%. Interestingly, the "other" fibers as a class outpaced the rest at 10% per year, representing an absolute gain of almost 80%, although of course they were moving up from a lower weight basis.

On a regional basis, the U.S. last year accounted for some 22% (3.3 billion lb) of total polyester fiber production, followed by Western Europe with 13% (nearly 2 billion lb) and Japan with 9% (some 1.3 billion lb). Making up the 8.4 billion lb balance were the other countries, which together contributed some 56% of the whole, substantially higher than for the other two main classes of synthetics, and reflecting a greater-than-average growth in recent years.

The Enka study notes that capacities in the "other" countries are rapidly being expanded. In terms of volume, the increase in Taiwan and China is the highest.

For the nylons, the U.S. also was the largest single source with about a third (2.5 billion lb) of the world supply. Western Europe held an 18% share (1.4 billion lb), and Japan 8% (600 million lb). Other countries made up the 41% (3.1 billion lb) difference.

Acrylic fibers was the only area in which the U.S. produced the least amount, as has been the case in all

previous years. The Enka market analysts put the profile at 34% (1.8 billion lb) for West European countries, 16% (800 million lb) for Japan, 12% (600 million lb) for the U.S., and 38% (2.0 billion lb) for the remaining countries combined.

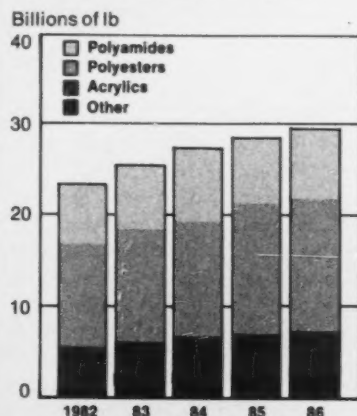
U.S. output both of the polyester and acrylic fibers has been moving lower at a rate of about 3% annually since 1980. Polyamides, on the other hand, have registered average growth of just less than 1% yearly during the past six years.

Looking at some of the overall factors that influenced the fibers business, the Enka review notes that "in 1986, the world economy was characterized by a continuation of the upswing in industrial nations. The economic development in the U.S. was overshadowed by a further increase in the deficit in the balance of payments. Economic growth in Western Europe continued at virtually the same pace as in 1985."

The lower price of oil helped push up consumption of a wide range of goods. For instance, sales of car and truck tires increased, which in turn called for greater quantities of fibers used in their production. On the other hand, the continuing fall in the dollar's value hit Europe's exports, and resulted in "substantially higher imports of textiles and clothing." Compounding the problem was the arrival in Europe of "very cheap man-made fibers, some at dumped prices."

Dermot O'Sullivan, London

Polyesters lead global synthetic fibers output



Source: Enka

NOTE

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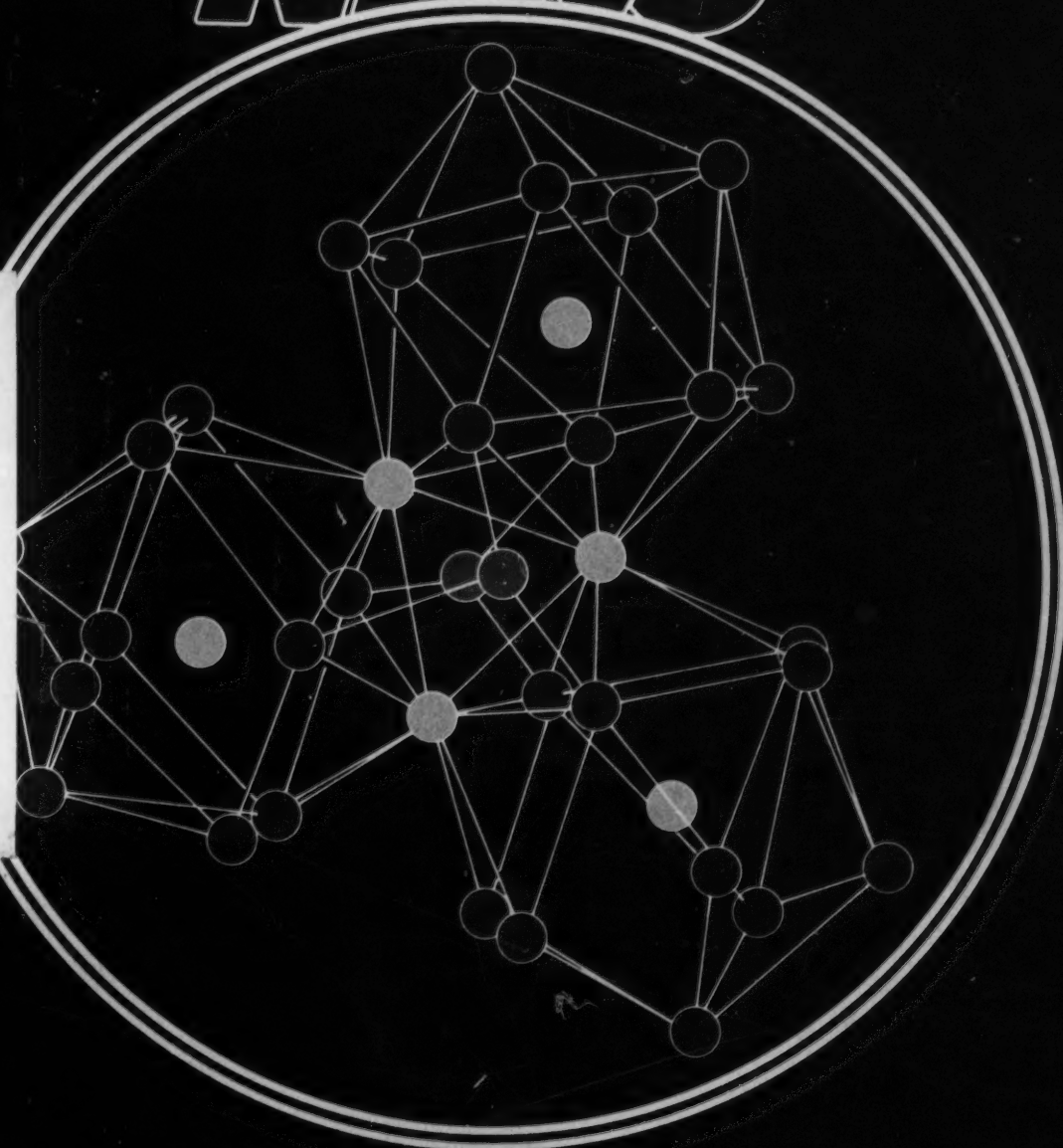
Fertilizer materials still in turmoil
A Key Chemicals Review
Page 19

MARCH 2, 1987

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CHEMICAL & ENGINEERING

NEWS



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METAL CLUSTERS

Catalytic promise drives research

Page 9

News of the Week

■ **Genetic basis for major mental disorder, manic-depressive illness, is found by a team of researchers in a 10-year study of an Amish community.** Page 6

■ **President Reagan's package on competitiveness, recently introduced in the House, gets tepid reception from the chemical industry.** Page 7

■ **Successful genetic surgery to cure neurological disease in mice offers insights into human diseases caused by single defective gene.** Page 7

■ **Hoechst-Celanese merger clears last major hurdle as Federal Trade Commission conditionally drops antitrust objections to merger.** Page 8

Cover: Metal framework of cluster, $[(CH_3C_6H_4)_3P]_{12}Au_{18}Ag_{20}Cl_{14}$, consists of icosahedral units; orange represents silver atoms at top and bottom of cluster, magenta represents remaining silver atoms, blue represents gold atoms on cluster's surface, and yellow-green represents gold atoms inside cluster

Business

Decline in demand for major fertilizer chemicals speeded by programs to reduce planted acreage and crop surpluses. Page 19

International Business

Global uranium demand is likely to rise more than 20 % by the year 2000, as number of nuclear power stations expands. Page 26

Government

House unexpectedly restructures some committees and subcommittees dealing with science. Page 29

Science

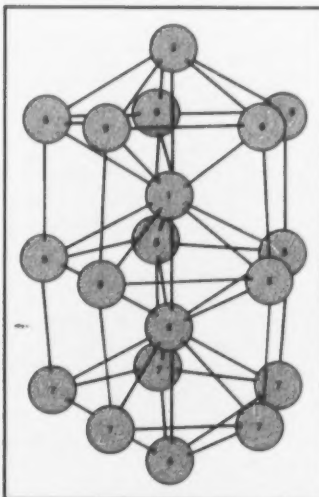
Acceleration of rate at which insects develop resistance to pesticides has led to concept of "resistance management." Page 32

Feline virus very similar to human AIDS virus has been identified and may serve as much needed animal model for AIDS research. Page 33

ACS News

Council will face three petitions to amend the ACS constitution and bylaws during next month's national meeting in Denver. Page 34

Letters	4
Concentrates	
Business	17
Government	28
Science/Technology	31
The Departments	
Awards	42
Meetings	45
Newsclips	60



News Focus

Emerging discipline of cluster chemistry holds much promise for catalysis, but its reach extends to theoretical exploration of matter. Page 9

Fertilizer Chemicals Face Another Bleak Year

Demand for ammonia, urea, wet-process phosphoric acid, potash will slip as fertilizer consumption is forecast to be less than 42 million tons

Bruce F. Greek, C&EN Houston

Forecasts for lower demand dominate the fertilizer outlook in the U.S. as the spring planting season begins in the South. A decline in total consumption of 5 to 8% in the fertilizer year ending June 30 will send it to below 42 million tons, or to about the 1983 level when the Payment in Kind (PIK) program was used to reduce crop surpluses. About 44.5 million tons of fertilizer were used in the 1986 fertilizer year, down 9% from 1985. Programs to reduce planted acreage will speed this year's decline in U.S. fertilizer use, and thus of the major fertilizer materials—ammonia, urea, wet-process phosphoric acid, and potash.

Fertilizer production, although also down, will be larger than consumption, because of a net export of material over imports. The trade balance has been slipping for some years as imports of fertilizer materials containing nitrogen increased rapidly while exports were slowing. Ammonium nitrate and urea have lost many of their export markets because of new production in other countries, and diammonium phosphate (DAP) is now the largest-volume fertilizer export, in terms of nutrients.

Efforts to reduce production of feed grains, especially corn, will lead to another decline in U.S. fertilizer consumption. Inventories of corn are estimated by the Fertilizer Institute to be more than 5.3 billion bushels

by the end of this marketing year in August.

Two programs, currently in place, are designed to reduce feed grain production. One is the Acreage Reduction Program (ARP) used last year, which permitted farmers to participate in price support programs if they would agree not to plant 20% of their land that could

in return for a payment of \$2.00 per bushel for grain that otherwise would have been grown on the acreage in the PLD. The deadline for farmers to enter the program is March 30, so the final amount of land idled for this year will not be known for some time.

The PLD program might have involved more acreage. At one time, rumors abounded that the additional acreage to be idled would be 30% above the 20% of ARP. Efforts by farm-oriented organizations such as the Fertilizer Institute to oppose another large cut in planted acreage resulted in the 15% level to be used in the PLD. Even so, the 15% level is forecast to reduce cropland another 20 million acres this year and to reduce fertilizer consumption another 2.5 million tons.

The new PLD program was announced late in October 1986, and fertilizer producers have been adjusting plant operations to account for expected lower demand this spring. Some units haven't been restarted following shutdown after the last growing season. Inventories of finished fertilizers also have been reduced, to bring them more in line with anticipated sales this spring.

Prices for most fertilizer materials have returned to levels of a year ago, resulting mainly from slowed production and reduced inventories. Although numerous producers have left the fertilizer business during the past year, plenty of capacity to make these materials remains unused. Such overcapacity coupled with acreage cuts causing lower demand, plus low farm commodity prices which reduce farmers' buying power, will hinder any recovery in the fertilizer business at present.

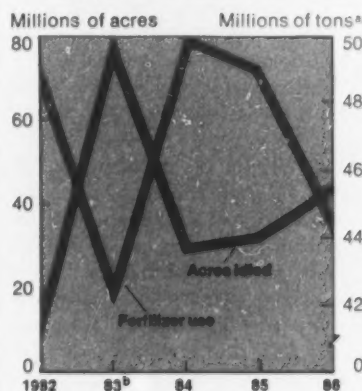
For details of the near-term outlook for the major fertilizer materials, please see the following pages.

Key Chemicals

be used to grow crops. This program is estimated to have taken about 18 million acres out of production in the 1986 crop year. Apparently it reduced fertilizer demand more than 4.4 million tons.

The new program being added to the existing one is called Paid Land Diversion (PLD). That program gives farmers the option of idling up to 15% more of their cropland—in addition to land idled under ARP—

Cuts in planted farm acreage hurt fertilizer use



Note: Crop years ending June 30. ^a Includes secondary and micronutrients. ^b Year of Payment in Kind (PIK) program. Source: Fertilizer Institute

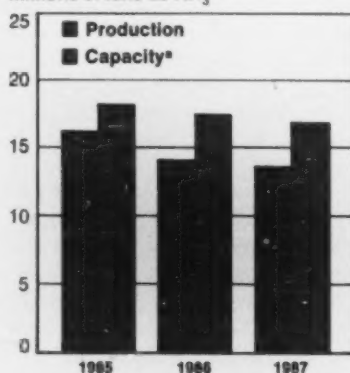


Ammonia

- **Output down**
- **Capacity falling**
- **Prices up seasonally**

PRODUCTION/CAPACITY

Millions of tons as NH_3



■ First quarter; some capacity idle but believed operable.

MAJOR PRODUCERS

CF Industries, Farmland Industries, W. R. Grace, Unocal, Williams Cos. (Agrico)

HOW MADE

Catalytic reaction of nitrogen from air and hydrogen from natural gas

MAJOR DERIVATIVES

Ammonium phosphates 20%, urea 20%, ammonium nitrate 15%, polymer intermediates 10%

MAJOR END USES

Fertilizers 80%, fibers and plastics 10%, explosives 5%

FOREIGN TRADE

Exports holding at about 500,000 tons; imports holding at more than 2.5 million tons

PRICE

\$100 to \$110 per ton on Gulf Coast

Ammonia production will fall this year, but not so much as last year. Plant capacity also will decline, but, again, less than in 1986. Anhydrous ammonia imports are expected to continue at about the same level as in 1986. However, imports of an ammonia derivative—urea, which competes with ammonia as a fertilizer material—again will increase, unless proposed anti-dumping regulations are adopted. Ammonia prices, which are now back up to levels of a year ago, may not fall so much as during the second half of 1986, unless reductions in demand (due to lower acreage planted) overexpand inventories.

Preliminary estimates indicate that U.S. ammonia output in 1986 totaled slightly more than 14 million tons, down 2.2 million tons, or about 14%, from 1985 production. Production last year was down more than 5.7 million tons from the peak year of 1980, or almost 30% from that year's total of 19.7 million tons.

Estimates for ammonia production this year vary as much as 500,000 tons on either side of the 14 million tons produced last year. However, most forecasts are for a slight decline because of high imports of ammonia and other nitrogen fertilizers, manufacturing unit closings, and less acreage planted. Nonetheless, a number of positive factors will help to maintain ammonia output, including lower gas prices and a probable increase in the amount of nitrogen fertilizer used per acre. The average decline now expected is less than 2% or about 200,000 tons, bringing the 1987 total to 13.8 million tons.

The amount of operable capacity during the year also is uncertain. For example, as 1987 began, Chevron Chemical mothballed about 500,000 annual tons of ammonia capacity at Pascagoula, Miss. Other capacity also may be idled later, depending on how strong sales are during the spring season, how well prices hold up after the season ends, and how consolidation in

the industry proceeds. If 1987 output totals 13.8 million tons, the 17 million tons of available capacity in the first quarter will be run at an average rate of 82%, which is higher than last year's rate but generally below annual rates earlier in the 1980s, many of which were more than 90% of nameplate capacity.

U.S. agricultural consumption of nitrogen as ammonia and its derivatives is forecast to decline 6 to 8% in 1987. The other major use of nitrogen in agriculture—animal feeds—is growing very slowly over the long term. Industrial uses, including explosives and various polymers, will grow little if any this year.

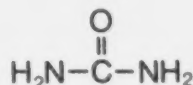
Imports and exports of ammonia and derivatives used in fertilizers are out of balance. This year imports of ammonia are expected to exceed exports by 2 million tons as nitrogen, about the same as last year. Other ammonia derivatives, such as ammonium nitrate and urea, have substantially larger imports than exports. Exports of diammonium phosphate (DAP) are much greater than imports, partially making up for the trade deficit in ammonia, ammonium nitrate, and urea.

With the fertilizer application season nearing its maximum for the year, inventories of ammonia and its derivatives have been built less than normal, according to some industry sources. The reason is the anticipated reduction in use forecast for the year.

Because of controlled inventory by the middle of last month, prices for ammonia already had moved to more than \$100 per ton at plants on the Gulf Coast. The price had fallen to less than \$70 per ton during a brief period last fall. Prices of ammonia could rise further next month if immediate consumption of fertilizers increases beyond expectations, if imports do not surge, and if natural gas prices increase. After the demand surge is over, producers will have to decide whether to hold down inventories and keep prices up or to sell at lower prices again.

Key Chemicals

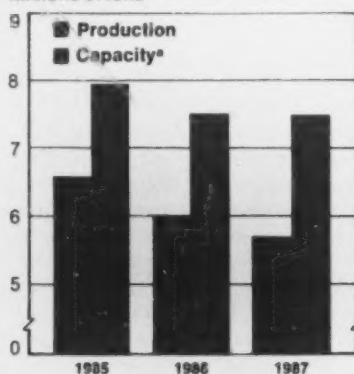
Urea



- **Production slowing**
- **Capacity on hold**
- **Prices pressured**

PRODUCTION/CAPACITY

Millions of tons



a First quarter; some capacity idle but believed operable.

MAJOR PRODUCERS

Arcadian, CF Industries, Farmland Industries, Unocal, Williams Cos. (Agrico)

HOW MADE

Reaction of ammonia and carbon dioxide under pressure

MAJOR DERIVATIVES

Urea-formaldehyde resins 5%

MAJOR END USES

Fertilizers 80%, animal feeds 10%, adhesives and plastics 5%

FOREIGN TRADE

Exports holding at about 1 million tons; imports rising to more than 3.5 million tons

PRICE

\$95 to \$105 per ton on Gulf Coast

Urea production will be harder hit by imports than any other of the fertilizer materials. Fast-rising imports of urea have led to proposals for antidumping duties, with decisions rumored to be made this month. Output of urea will fall in 1987, but whether the decline will be large or small will depend on how imports are restricted and how prices respond to those restrictions.

The substantial excess of exports of urea over imports in the early 1980s changed in 1983 when urea imports soared and exports fell steeply. In 1986, imports probably approached 4 million tons, up from about 2.2 million tons in 1985 and 1984. Exports declined to less than 1.2 million tons in 1985, and slipped further last year. The net imports of urea in 1986 account for the second largest part of the trade deficit in nitrogen for fertilizers after net imports of ammonia.

U.S. production of urea likely will be down again in 1987, as about a quarter of the year will have passed before any restrictions, other than prices, could be placed on urea imports. The decline in output this year will be about 5% from 1986 to 5.7 million tons. Output last year was down 9% from 1985. The historical high for U.S. urea production occurred in 1981, when slightly less than 8.1 million tons were produced from a little more than 8.1 million tons of capacity.

Operable nameplate capacity for urea in the U.S. currently is about 7.5 million tons per year. Urea plants are located adjacent to ammonia plants, which are the source of the other raw material going into urea—carbon dioxide. Some capacity now running may be shut down after the spring planting season if prices decline because of low-price imports. If production totals 5.7 million tons in 1987, available capacity at the beginning of the year will be run at about 75%, well down from historical performances.

In many instances urea manufacture aids ammonia plant operation, unless urea prices are very low. A man-

ufacturing complex making ammonia, urea, ammonium nitrate (by burning ammonia to make nitric acid, which is reacted with more ammonia), and solutions of urea and ammonium nitrate can be run more efficiently and with a better return than a plant making merchant ammonia alone. Urea-ammonium nitrate (UAN) solutions have been, by far, the fastest-growing fertilizer material of the past five years, because of the ease of application.

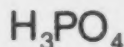
Urea provides a source of nonprotein nitrogen in animal feeds. It also is used to make urea-formaldehyde and melamine resins and chemical intermediates. Feed and industrial uses as a group account for less than 20% of urea consumption and are growing marginally.

Therefore, urea consumption hinges on fertilizer demand, with all of the uncertainties due to weather and acreage restrictions. Exports of urea are forecast to decline slightly again this year, but will remain near 1 million tons. How much imports will offset U.S.-produced urea in fertilizer markets could further influence production for the year.

Similar to those of ammonia, prices of urea have recovered to levels of a year ago, or to about \$100 per ton at Gulf Coast plants. This price is well above levels of last fall when, for a short period, prices fell to about \$75 per ton.

Urea imported from East-bloc countries had been selling for less than \$70 per ton at Gulf Coast ports. Some of the imported urea has been poor-quality prilled material with a high dust content, and reportedly dissolves poorly when used to make UAN solutions.

Demand for urea is not expected to rise this year and exports may decline. If urea imports are drastically reduced, the urea not coming into the U.S. will move to countries once supplied by U.S. exports. Therefore, the outlook for U.S. urea production remains flat until domestic fertilizer demand increases significantly.

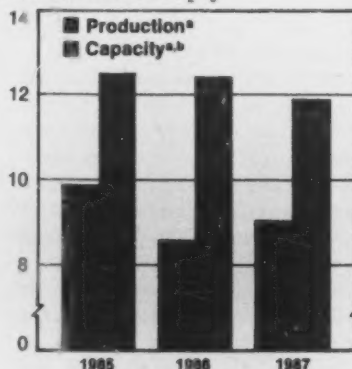


Phosphoric acid

- **Production to recover**
- **Capacity slipping**
- **Prices higher**

PRODUCTION/CAPACITY

Millions of tons as P_2O_5



^a Wet process acid. ^b First quarter; some capacity idled and not expected to operate again.

MAJOR PRODUCERS

CF Industries, Freeport Chemical, International Minerals, Occidental Agricultural Chemicals, Texasgulf

HOW MADE

Phosphate rock reacted with sulfuric acid, with product phosphoric acid purified and concentrated

MAJOR DERIVATIVES

Ammonium phosphates 85%, triple superphosphate 10%

MAJOR END USES

Fertilizers 95%, animal feeds 5%

FOREIGN TRADE

Exports holding at about 1.2 million tons; imports small, less than 25,000 tons

PRICE

\$250 per ton of 100% P_2O_5

Output of wet-process phosphoric acid this year will rise because export demand for a major derivative—diammonium phosphate (DAP)—will increase. But U.S. consumption, mostly in various forms of phosphate and mixed fertilizers, will decline again because planted acreage will be smaller, according to forecasts for the 1987 crop year ending June 30. These developments will combine to hold phosphoric acid output well below the 1985 level.

Uncertainties, however, cloud the forecasts. For example, some speculate that the relatively warm winter and an early spring will result in a higher application rate per acre and thus spur fertilizer demand this year in spite of plans to reduce planted acreage. There also is a question of export demand for DAP, because of uncertainties about inventories in countries such as India and China that in recent years have imported large quantities of DAP. These and other influences on demand could cause variations in output of wet-process phosphoric acid as large as 1 million to 2 million tons as P_2O_5 or more than 20%.

Phosphoric acid output this year probably will exceed 9 million tons as P_2O_5 . About 400,000 additional tons of "furnace" or "thermal" phosphoric acid will be made by burning elemental phosphorus produced in an electric furnace. This acid will be consumed in detergent materials, foods, beverages, and other nonfertilizer uses for which high purity is important. "Wet acid" production will be about 500,000 tons higher than the estimated 1986 production of 8.6 million tons, an increase of about 6%. The 1986 output of wet-process phosphoric acid fell 14% from the 9.9 million tons produced in 1985. That decline continued and accelerated the decline that began after 1984's record production of 10.7 million tons.

Capacity to make wet-process phosphoric acid also has been declining. Not only have obsolete plants been shut down, but other capacity has been closed as a result of mergers and

bankruptcies. Expansions of capacity during the past two years have been meager, less than 500,000 tons of annual capacity as P_2O_5 . At the beginning of 1987, operable capacity totaled about 12 million tons as P_2O_5 , yet nearly a quarter of this capacity was idle, and only part of the idled capacity is expected to be run this spring to meet both domestic and export demand for phosphate fertilizer materials.

For all of the calendar year, the average plant operating rate will be barely more than 75%. This rate, and the 1986 rate of less than 70% of the available capacity as that year began, contrasts sharply with operating rates of close to 100% that once were considered typical for the wet-process phosphoric acid industry.

The low operating rates resulted in a spate of changes of ownership and operations in the phosphoric acid industry. The complex dealings of Freeport-McMoRan through its subsidiaries is one example. Last month, Freeport-McMoRan Resource Partners, a limited partnership, finalized an agreement to buy Agrico Chemical, the fertilizer producing company owned by Williams Cos., with closing scheduled later this year. Earlier, Freeport had moved to acquire a phosphoric acid plant and phosphate rock mine from Beker Industries. Freeport previously had bought a plant to make DAP. These moves, if all are completed, could make Freeport second in capacity size as a producer of phosphoric acid and would make the company a large basic producer of ammonia.

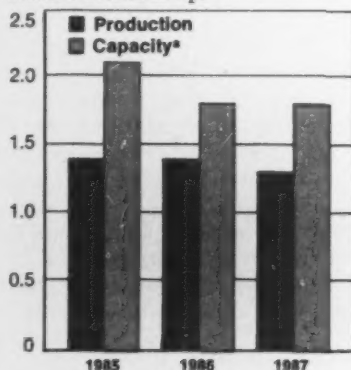
After declining rapidly during 1986, prices for phosphoric acid currently have moved back to about the levels of a year ago. Sulfur prices declined last fall, which helped phosphoric acid margins. But with corn and cotton plantings forecast to be down 7 to 10% this year, prices again could decline unless inventories are controlled and held at the relatively low levels of the beginning of the year.

Potash

- **Production to decline**
- **Capacity down**
- **Prices up slightly**

PRODUCTION/CAPACITY

Millions of tons as K₂O



■ First quarter; some capacity idle, restarting uncertain.

MAJOR PRODUCERS

AMAX, International Minerals, Lundberg Industries, Texasgulf, Vertac Fertilizer & Minerals (New Mexico Potash)

HOW MADE

Shaft and solution mining of potassium salts, mainly the chloride, and subsequent purification

MAJOR DERIVATIVES

Various potassium salts 5%

MAJOR END USES

Fertilizers 95%

FOREIGN TRADE

Exports holding at about 500,000 tons as K₂O; imports may decline slightly from more than 4 million tons as K₂O

PRICE

\$50 to \$60 per ton at mining sites

U.S. potash production and consumption again will fall in 1987. The rate of decline for both measures will be about the same, but in terms of volume production will decline much less than consumption. Imports will account for more than 80% of U.S. consumption. No important changes in potash capacity are forecast for this year.

This year's decline in agricultural potash consumption will result from cuts expected in acreage planted this spring as part of programs to reduce crop surpluses. In the fertilizer year ending this June 30, consumption of materials containing potassium is estimated to total 4.5 million to 4.6 million tons as K₂O, down from the 5.03 million tons consumed in the 1985 fertilizer year. This will be the first year since 1983 that consumption has fallen below 5 million tons, and it could be the lowest since 1975.

U.S. production of potash during calendar year 1987 also is expected to decline about 8%, to less than 1.3 million tons as K₂O. It will be down about 100,000 tons from 1986 output, estimated to be slightly below 1.4 million tons, and from 1985 output of 1.43 million tons.

Potash capacity in the U.S. is concentrated around Carlsbad, N.M., and has been declining for some time. The quality of ore available continues to fall, causing mining and other costs to rise. Production costs have increased faster than selling prices, which are pressured by lower-cost production at other locations. Some mines have been closed. Mines and other facilities currently believed capable of potash production have a combined capacity of about 1.8 million tons per year as K₂O. Some of the capacity was not operating as 1987 began. Based on an anticipated U.S. output of 1.3 million tons, the operating rate for 1987 may average 72%.

About 4 million tons of potash as K₂O will be imported in 1987, mainly from Canada, to meet anticipated U.S. demand. Exports of U.S.-produced pot-

ash are expected to be about 500,000 tons in 1987. These exports go to such places as South America because transportation costs from New Mexico are lower than from Canada. In addition to exports to the U.S., Canadian producers, many of which are subsidiaries of U.S. firms, export another 2.0 million to 2.5 million tons per year of potash to other countries.

Like other fertilizer materials, potash also is in worldwide overcapacity. Global capacity is estimated to be 40 million metric tons as K₂O; 1986 output is estimated to have been more than 29 million metric tons. Inventory building last year apparently was large, possibly more than 2 million metric tons. This put pressure on prices everywhere and caused wide variations in shipments to various consuming countries outside North America.

Some new capacity to produce potash has started up in eastern Canada in the province of New Brunswick. Other mining and processing facilities have been proposed for the same area, the first Canadian facilities outside Saskatchewan. Most of this potash is destined for export markets, some of which are in the eastern U.S. The mines have relatively large capacities because investment costs require that economics of scale be large.

Besides use as a fertilizer material, some potash—estimated to range from 300,000 to 400,000 tons per year—is consumed in making various chemicals in the U.S. and Canada. The industrial uses of potash are mainly specialties and, as a group, are not growing very fast in their needs for potash raw material.

With the current situation in fertilizer demand, the near-term prospects for U.S. potash production are for small declines. Longer term, agricultural use could return to the levels of the early 1980s. By that time, however, new Canadian sources could have production costs so far below those for New Mexico operations that more capacity reductions will occur there.

Strong Rise Forecast in Global Uranium Demand

Key is rapid expansion in nuclear power stations, whose electricity-generating capacity by 2000 may reach 373 gigawatts, up 63% from 1986

Dermot A. O'Sullivan, C&EN London

Taken at face value, the near-term prospects for uranium suppliers seem reasonably good, according to the Uranium Institute. In its latest review (the fourth to date) of the global uranium market, the London-based institute projects demand at the end of the 20th century to fuel commercial nuclear electricity-generating stations throughout the noncommunist countries at about 52,000 metric tons, an increase of almost 24% from the 42,000 metric tons or so used last year.

The Uranium Institute was set up in 1975; its members comprise a number of bodies with interests in the nuclear fuel cycle in Australia, Belgium, Brazil, Canada, Finland, France, Gabon, Italy, Japan, Namibia, South Africa, Spain, Sweden, Switzerland, Taiwan, the U.K., the U.S., and West Germany, as well as Euratom, a sister organization of the European Economic Community.

In the year 2000, West European uranium use will account for 40% (20,800 metric tons) of the global noncommunist total. Next will come the U.S. with 27% (14,300 metric tons), followed by the Far East with 24% (12,500 metric tons). The 9% balance (4,700 metric tons) will be shared by other countries.

This uranium demand profile will differ somewhat from last year's. Then, Western Europe took 44% (18,800 metric tons), and the U.S. nearly 35% (14,700 metric tons). The

Far East accounted for only 15% (6,400 metric tons). The 6% balance (2,400 metric tons) went to other countries.

The anticipated rise in uranium demand is based on the rapid expansion in nuclear-fueled power stations foreseen in the years leading up to the 21st century. According to the institute's data, which have been gleaned from various government and industry sources, overall nuclear electricity-generating capacity by 2000 might reach 373 gigawatts (GW), 63% more than last year.

In Japan, for instance, the rise will be close to 141%, from about 25 to 59 GW. In France, a 77% increase is being predicted to 68 GW in 2000, at which level nuclear's share will stand at 78% of France's total electrical energy output. For the U.S., there will be a more modest 28% or so expansion to 111 GW by 2000. On the other hand, the 87-GW installed nuclear capacity in 1986 (some 16% of the U.S. electricity total) far exceeded that in any other country.

Significant as the projected rise in nuclear generating capacity may appear, the growth has been trimmed from the Uranium Institute's earlier predictions. Compared with those made in the second review, in 1981, and the third, in 1984, the forecast total for 1990 dropped 16%, from 352 to 295 GW. The current review's figure of 292 GW in 1990, however, is only down 1% from the projection made in 1984. "It is, therefore, regarded as a relatively secure estimate," the institute's analysts contend. "The nuclear industry appears to be entering a period of stability."

"The estimate for 1995 has been progressively revised downward from the 1981 forecast, first by 18% in 1984, and then by a further 8% to

331 GW in 1986. This decrease reflects the higher number of units for 1995 that were under construction or on order in 1981 or 1984, but were deferred or canceled by 1986.

"For the year 2000, which was not covered in previous reports, few possible shutdowns, delays, or cancellations as a result of the 1985 Chernobyl accident in the Soviet Union have been incorporated. At the time of writing, it was too soon after the accident to allow reliable judgments to be formed."

The institute's analysts concede that it is difficult to assess all the possible effects of the accident. Some long-term consequences are inevitable. Even though it was caused primarily by human error, new safety measures could be required for all reactors, especially for those that don't have containment buildings. It also is likely that nuclear plants in some countries may be shut down, deferred, or canceled, reflecting a change in public attitude to nuclear power.

"The underlying assumption of this report is that operating nuclear generating plants will not be shut down, and those under construction in 1986 will be completed," the institute maintains. "If from 1986 no new reactor orders were placed as a result of Chernobyl, 1995 installed nuclear capacity would be about 2% less than the forecast of 331 GW. By the year 2000, if there were no new orders, projected capacity would be about 328 GW, some 12% lower than the estimate of 373 GW."

Chernobyl apart, there are other factors to be taken into account, the interplay of which affects decisions by governments on whether to extend nuclear generating capacity. For instance, as a result of the recent decline in oil and coal prices,

short-term economics could delay construction, especially where there is some excess fossil fuel electrical-generating capacity. And there are noneconomic aspects, such as the environmental impact of a nuclear energy source, the disposal of radioactive waste, and the like, that will influence investment decisions.

The Uranium Institute acknowledges that "the amount of future nuclear generating capacity could vary depending on the interplay of economic growth, interfuel competition, and factors such as concerns about nuclear waste and changes in public opinion about nuclear energy." But it makes the point that "This report's analysis shows that in the long term, nuclear power is expected to retain its economic advantage for generating electricity in most areas. Furthermore, the prices at which utilities would consider using excess fossil fuel capacity in preference to nuclear plants are below the 1986 marginal production costs for coal and oil."

As nuclear power generation expands, demand for uranium to fuel the plants also increases. However,

the two don't grow exactly in step. On the one hand, uranium requirements change some two years in advance of the corresponding changes in generating capacity because of the lead time needed for the uranium to be processed into fuel. In addition, most utility companies maintain a fuel stockpile over and above what they have undergoing conversion, enrichment, and fabrication. These stocks are intended as an insurance against supply disruption.

The institute's report estimates that global consumer inventory at the beginning of last year was 120,000 metric tons of uranium. That represents about 40% more material than is needed to sustain two years' forward requirement. Procurements, therefore, are expected to be lower than actual need until 1991, when the aggregate excess fuel inventories are expected to be utilized. Purchases are forecast to be 41,600 metric tons in 1990, 48,500 metric tons in 1995, and 51,700 metric tons in 2000.

Other factors enter into the equation for making forward projections of fuel demand. Developments in the industry, driven by economic

pressures, offer a number of ways of saving uranium. Examples are the more extensive use of recycling technology, and improved fuel management techniques. Combined, they could reduce requirements in 1995 about 14%, and in 2000 about 20% below those needed in their absence.

"The extent to which they will be used introduces uncertainty into projections for reactor requirements—the uranium needed to fuel reactors," the report admits. "Both reactor requirements and uranium procurements (uranium purchases intended by reactor operators each year) will tend to increase somewhat more slowly than the growth of western nations' installed nuclear capacity. The result is that actual demand may turn out to be somewhere between the estimates for reactor requirements, and those for uranium procurements."

On this basis, the institute's forecasters have adjusted downward their demand projections. In 1990, for instance, they calculate that uranium demand could be 42,700 metric tons, 4% less than the theoretical need after taking account of fuel management improvements, etc. Likewise, in 2000 it might be 48,600 metric tons, 7% less than expected.

In the past, uranium producers have always been able to supply what have been perceived at the time as the potential needs of western nations' nuclear industry. Output rose steadily throughout the 1970s, peaking in 1980 at 44,000 metric tons. Since then, it has been on the decline to a level of 34,700 metric tons in 1985—the latest year for which data are available.

The 21% fall in production between 1980 and 1985 masks much greater changes that have taken place on a regional basis. The U.S. until a few years ago was the biggest source of uranium. Output at its height in 1980 stood at 16,800 metric tons, some 38% of the non-communist world total that year. By 1985, it had declined 75% to 4200 metric tons. Canada, in the meantime, has emerged as the largest producer. Its 1985 output of almost 11,000 metric tons accounted for a third of western nations' total. South Africa came second with nearly 5000 metric tons.

Uranium demand in 2000 will be about 20% higher . . .

Thousands of metric tons	1986	1987	1988	1989	1990	1995	2000	Change 1986-2000
Western Europe	18.8	19.6	19.5	19.6	19.3	20.4	20.8	10.6%
U.S.	14.7	14.4	14.6	14.5	14.2	14.2	14.3	-2.7
Far East	6.4	6.8	7.2	7.5	7.8	10.7	12.5	95.3
Others ^a	2.4	2.5	2.7	2.8	3.2	4.1	4.7	95.8
TOTAL	42.3	43.3	44.0	44.4	44.5	49.4	52.3	23.6%
ADJUSTED TOTAL^b	41.3	42.3	42.9	43.0	42.7	45.4	48.6	17.7%

. . . to meet prospective rise in nuclear generating capacity

Thousands of metric tons	1986	1987	1988	1989	1990	1995	2000	Change 1986-2000
U.S.	86.6	97.6	104.3	105.5	106.6	108.9	111.2	26.4%
France	38.2	44.2	48.3	51.5	54.0	62.9	67.7	77.2
Japan	24.5	27.9	28.7	29.3	31.5	49.0	59.0	140.8
West Germany	17.8	19.2	19.2	21.7	23.0	23.0	24.3	38.1
Canada	10.8	11.6	11.6	12.5	13.4	15.8	15.8	48.3
U.K.	9.8	11.0	12.3	12.3	12.3	11.4	13.8	40.8
Sweden	9.6	9.6	9.6	9.6	9.6	9.6	9.6	0.0
Belgium	5.5	5.5	5.5	5.5	5.5	6.7	6.7	21.8
Spain	5.5	5.5	6.5	7.5	7.5	6.4	10.3	87.3
Others ^a	20.8	22.8	23.8	24.7	26.3	34.8	54.5	162.0
TOTAL	228.9	254.7	269.8	280.1	291.7	330.5	372.9	62.9%

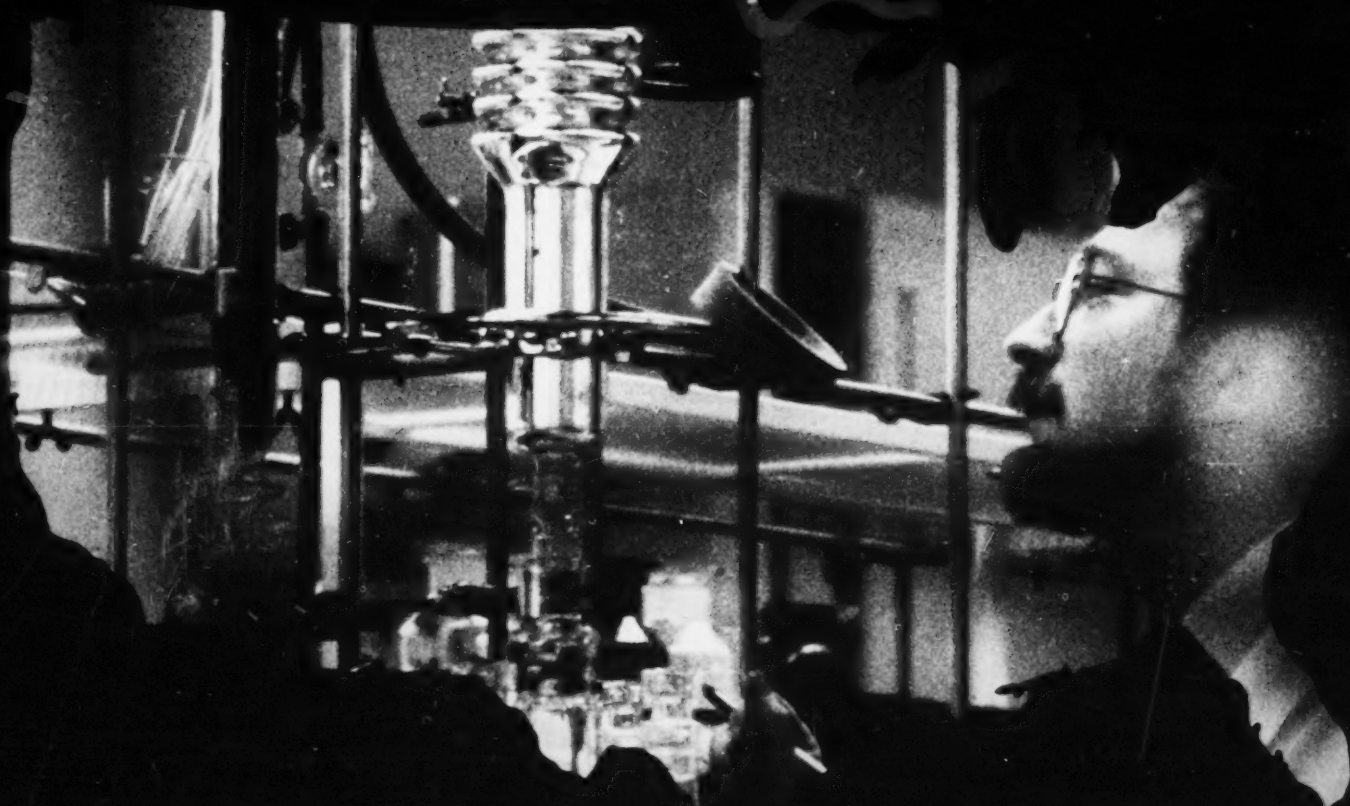
^a Noncommunist countries, but including Yugoslavia. ^b Total allowing for recycling of reprocessed fuels.
Source: Uranium Institute

MARCH 9, 1987

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CHEMICAL & ENGINEERING

NEWS



Chemistry & Public Policy

The links have been forged
over many years

Page 20

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News of the Week

■ Office of Science & Technology Policy faces special challenges in wake of shakeup of White House staff. **Page 4**

■ First results of National Ozone Expedition to Antarctica indicate that ozone loss occurs in layers. **Page 5**

■ National Academy of Engineering elects 82 engineers to academy membership, including several in chemically related areas. **Page 6**

■ Sterling Group, an investment firm specializing in leveraged buyouts, is scheduled to purchase Corpus Christi Petrochemicals and ICI America's ethylene oxide/glycol business. **Page 6**

Cover: Photo courtesy of W. R. Grace

Letters	2
Editor's Page	3
Concentrates	
Business	7
Government	11
Science/Technology	13
The Departments	
ACS Focus	33
ACS News	34
Meetings	35
People	36
Newsclips	48

Business

In 1986, chemical industry productivity rose for the fourth straight year, as unit labor costs fell. **Page 9**

Government

Distribution system of federal R&D funds to universities is examined by General Accounting Office. **Page 12**

Science

Evidence of tunneling's contribution to the rates of chemical reactions in the gas phase is uncovered. **Page 14**

Manic-depressive illness and Alzheimer's disease are two major mental disorders for which genetic link has been found. **Page 15**

Perkin Medal

J. Paul Hogan and Robert L. Banks are recognized for their pioneering work on polypropylene and polyethylene. **Page 30**

Books

Martin Kenney examines the development of biotechnology from the academic laboratory to commercial reality. **Page 31**



Special Report

The chemical sciences have become increasingly enmeshed with public policy issues, from the early days of alchemy to the industrial revolution to the present. **Page 20**

Chemical Industry Productivity Continued To Rise in 1986

William J. Storck, C&EN New York

Productivity in the U.S. chemical industry rose once again in 1986 as unit labor costs fell, according to recently released government figures. It was the fourth straight year that both measures improved.

Since the recessionary years of the early 1980s, the chemical industry, and indeed U.S. industry as a whole, has been taking measures to increase productivity. The large reductions in force in employment, process improvements, and the trim-

ming back, where possible, of employment costs have all been a part of this effort. And it has been working. Since 1982, the rate of growth for productivity in the U.S. chemical industry has averaged almost 7% annually. And the cost per unit of labor output has declined at an average rate of about 2% per year.

Productivity is defined as output per workhour, calculated by dividing the Federal Reserve Board's index for production by the Labor Department's index for aggregate weekly hours of production. Unit

labor costs are labor costs per unit of output, figured by dividing indexes for wages by indexes for output per workhour.

According to C&EN's calculations, productivity for chemicals and allied products in 1986 increased 5.5% from 1985 to an index of 142.1 (1977 = 100), more than twice as fast as the 2.5% increase seen for all manufacturing. The index for all manufacturing for the year was 138.9. The improvement for chemicals resulted from a 4.6% increase in production and a 0.9% decline in

Productivity for chemicals gained 5.5% in 1986, for all manufacturing only 2.5% . . .

Indexes, 1977 = 100	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976
CHEMICALS AND ALLIED PRODUCTS											
Production	132.9	127.1	121.6	113.9	103.8	112.6	106.4	113.3	106.3	100.0	92.0
Workhours	93.5	94.3	95.0	93.9	95.2	101.7	101.0	103.1	102.2	100.0	97.3
Productivity	142.1	134.8	128.0	121.3	109.0	110.7	105.4	109.9	104.0	100.0	94.6
Hourly production wages	186.1	180.1	172.7	164.8	155.0	141.8	129.2	118.2	109.2	100.0	91.9
Unit labor costs	130.9	133.7	135.0	135.9	142.2	128.2	122.6	107.6	105.0	100.0	97.2
ALL MANUFACTURING											
Production	129.2	126.4	123.4	113.9	102.2	110.5	108.2	110.7	106.1	100.0	94.1
Workhours	93.0	93.3	94.8	88.2	87.0	97.9	98.9	106.2	104.5	100.0	96.1
Productivity	138.9	135.5	130.1	124.8	117.5	112.9	109.4	104.2	101.5	100.0	97.9
Hourly production wages	171.1	166.9	161.5	155.4	149.6	140.7	128.1	118.0	108.6	100.0	91.9
Unit labor costs	123.2	123.2	124.1	124.4	127.3	124.7	121.5	113.2	107.0	100.0	93.8

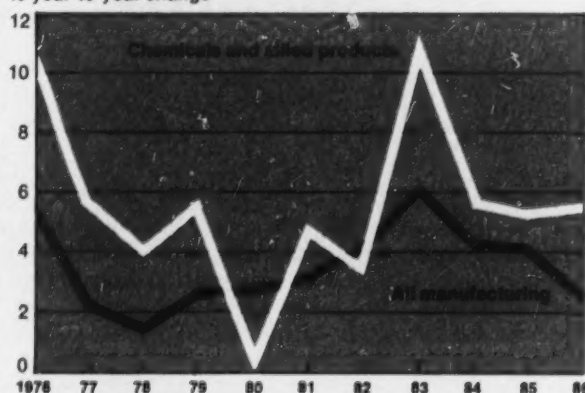
. . . but in fourth quarter productivity for chemicals fell and for all manufacturing rose

Indexes, 1987 = 100	Quarters, 1986				Quarters, 1985				Quarters, 1984		
	4th	3rd	2nd	1st	4th	3rd	2nd	1st	4th	3rd	2nd
CHEMICALS AND ALLIED PRODUCTS											
Production	133.4	134.1	132.8	131.3	127.9	128.1	126.8	125.8	123.6	122.8	120.4
Workhours	94.2	93.4	93.1	93.4	93.8	93.9	94.5	95.1	94.9	95.4	94.9
Productivity	141.7	143.6	142.7	140.6	136.3	136.4	134.1	132.3	130.2	128.8	126.9
Hourly production wages	188.7	186.9	184.8	184.1	183.9	180.7	178.6	177.3	176.5	173.5	171.2
Unit labor costs	133.2	130.2	129.5	130.9	134.9	132.5	133.1	134.1	135.5	134.7	134.9
ALL MANUFACTURING											
Production	130.4	129.4	128.4	128.4	127.4	126.8	126.2	125.3	124.9	124.6	123.0
Workhours	93.1	92.5	92.8	93.6	93.5	92.9	93.0	93.8	94.6	95.1	95.2
Productivity	140.1	139.9	138.3	137.3	136.3	136.5	135.6	133.7	132.0	131.1	129.1
Hourly production wages	172.2	171.0	170.8	170.5	169.4	167.8	167.0	163.6	163.8	161.6	160.6
Unit labor costs	122.9	122.2	123.5	124.2	124.3	122.9	123.2	122.4	124.1	123.3	124.4

Sources: Federal Reserve Board, Department of Labor

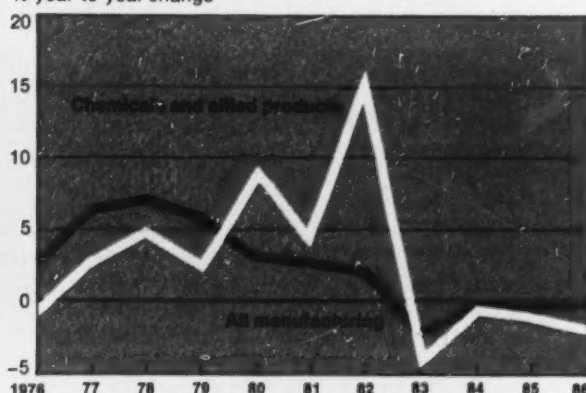
Annual chemical productivity gains still outpace those for all manufacturing ...

% year-to-year change



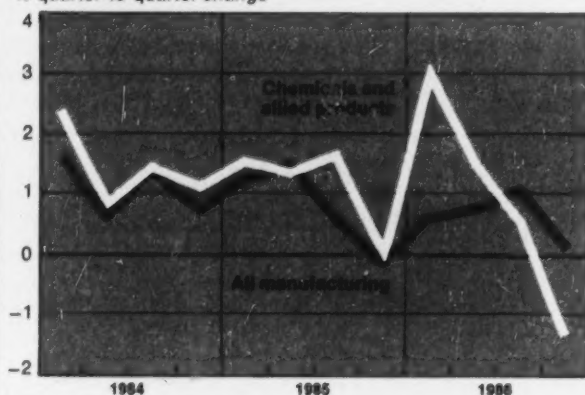
... and unit labor costs for chemicals continue to fall faster

% year-to-year change



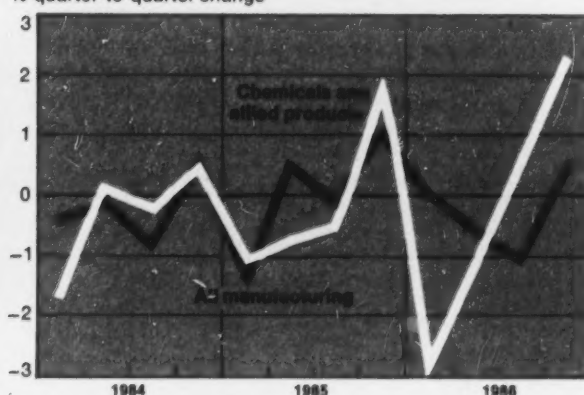
Quarterly growth of chemical productivity has ended ...

% quarter-to-quarter change



... and unit labor costs for chemicals have increased in past two quarters

% quarter-to-quarter change



Note: Productivity is output per workhour, calculated by dividing indexes for production by indexes for workhours of production employees. Unit labor costs are labor costs per unit of output, calculated by dividing indexes for wages by indexes for output per workhour. Sources: Department of Labor, Federal Reserve Board

aggregate workhours. Again these measures were better than those for all manufacturing, for which output increased 2.2% and workhours fell 0.3% from the year before.

Unit labor costs improved in the chemical industry by declining 2.0% from 1985 to an index of 130.9. This measure for all manufacturing was the same as it had been the year before at 123.2. Hourly production wages for chemicals, however, increased faster than for all manufacturing, rising 3.3% compared with 2.5%.

Some may question how much longer the chemical industry can sustain the kind of productivity increases of recent years. And, indeed, some signs of weakening in the growth rate have emerged. The first

sign was that, though the rate of growth was higher in 1986 than in 1985—5.5% compared with 5.3%—the quarter-to-quarter rate of change for productivity has been slowing for the past three quarters. After garnering a respectable 3.2% growth rate in the first quarter of 1986 over the final three-month period in 1985, the quarterly rate has been dwindling. In the second quarter, growth was 1.5%, in the third quarter 0.6%, and in the final period of 1986, productivity actually contracted 1.3%. This is only the fourth quarter-to-quarter decline in productivity since the beginning of 1982 and the worst since the fourth quarter of 1981.

Much the same picture emerges for chemical unit labor costs. After

falling 3.0% and 1.1% in the first and second quarters of 1986, unit labor costs in the chemical industry, on a quarter-to-quarter basis, increased 0.5% in the third quarter and an alarming 2.3% in the fourth quarter. This is the largest quarter-to-quarter increase since fourth-quarter 1983 and the first time since 1982 that the industry has seen back-to-back quarterly increases in unit labor costs.

However, the decline in productivity and the increase in unit labor costs in the fourth quarter are the result of a slight 0.5% fall in production from the previous quarter. A seasonal pickup in the first quarter of this year may easily put the chemical industry on the track of improved productivity once again. □

Academia's Federal R&D Funding Probed

A frequent complaint about the federal research and development funding that goes to universities is that it is concentrated too much in too few large universities. Another complaint has been that an "old boy" network operates in the peer review process that keeps new investigators from getting a fair share of the government largess.

Sen. Mark O. Hatfield (R.-Ore.), as chairman of the Senate Committee on Appropriations in 1985 (now the ranking minority member), asked the General Accounting Office to examine federal research funding to see if the complaints were true. The GAO report released late last month finds that some universities do get large percentages of research funds, but there is a lot of variation as well. The report also finds some justification for the current peer review process.

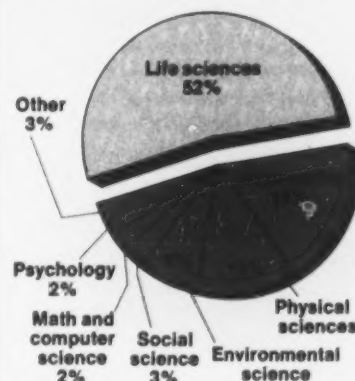
GAO examined the top 100 institutions receiving federal funds from the National Science Foundation and the National Institutes of Health in

fiscal 1967 and compared them with institutions receiving the most funds in fiscal 1984. It says that distribution of research funds relies on several factors, including demographic and socioeconomic factors, total state population, number of employed scientists and engineers, number of Ph.D. degrees granted, and state per-capita spending on higher education. By concentrating on the 20 universities with the largest federal funding, GAO investigators determined that in the past 17 years there has been little change in which universities receive the most funds. Only four institutions have changed ranking in that time.

But, when GAO looked at individual science categories and how funding was divided, a different mix resulted. For instance, in the physical sciences area, which includes chemistry, six universities among the top 20 with the most funding for physical sciences are not among the top 20 in terms of total federal R&D funding. The same holds true for the other categories. What is happening, GAO says, is that so much federal research money is going into life sciences research that schools with large programs in this area, particularly those with research medical schools, have a bigger pool to draw from. The result is that almost all the top 20 universities in the life sciences category are also the top 20 in overall R&D funding. Physical sciences receive only 13% of research funds, so emphasis on physical sciences at a university probably means less overall funds, and therefore a lower ranking.

The issue of peer review has been studied before and defies simple analysis. GAO points out that measuring the validity of peer review is difficult because it is so subjective, involving the judgment of many people on the merits of a particular research proposal. GAO compared the distribution of grants under the open peer review system of NSF and NIH with the internal review

Life sciences dominate in federal research funding



Source: National Science Foundation

system used by the Department of Defense. The only conclusion that could be reached was that the internal DOD process concentrated funds in fewer states and institutions than did the outside review process.

Another aspect of peer review examined was the success rate of different colleges in getting proposals accepted. GAO found that among the 20 highest-funded schools, the success rate averaged 43% for NIH and 50% for NSF. Institutions ranking below the top 20 had success rates averaging 38% at NIH and 35% at NSF. Although the success rate for the lower-ranked schools was lower, the difference between the higher-ranked and lower-ranked schools is not very large. GAO reached no conclusions and made no recommendations regarding peer review of research proposals, but says peer review, by itself, does not account for the concentration of federal research funds to institutions.

Copies of the GAO report, "University Funding: Patterns of Distribution of Federal Research Funds to Universities," can be obtained by writing to the U.S. General Accounting Office, P.O. Box 6015, Gaithersburg, Md. 20877.

David Hanson, Washington

MIT gets most federal physical sciences funds

Physical sciences funding rank	Total federal R&D rank
1 Massachusetts Institute of Technology	2
2 Stanford University	3
3 Cornell University	7
4 California Institute of Technology	29
5 University of Wisconsin, Madison	9
6 University of Illinois, Urbana	18
7 University of California, Berkeley	14
8 University of Pennsylvania	13
9 University of Rochester	25
10 University of Chicago	19
11 University of California, Los Angeles	6
12 University of Texas, Austin	22
13 University of Maryland, College Park	44
14 Harvard University	10
15 Michigan State University	38
16 University of California, San Diego	8
17 Columbia University, Main Division	5
18 Indiana University	49
19 Yale University	11
20 Johns Hopkins University	1

Note: Data from fiscal 1984. Source: General Accounting Office

NOTE

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Cov. 1, pgs. 1, 7-13

MARCH 16, 1987

CHEMICAL & ENGINEERING

NEWS

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**Polymer
Composites**

Versatile materials
find new uses in
many fields
Page 7

News of the Week

■ Chlorine compounds derived from chlorofluorocarbons are further implicated in ozone layer depletion in Antarctica. **Page 4**

■ House hearing investigates global issues of ozone depletion in the stratosphere. **Page 5**

■ Eli Lilly & Co. receives FDA approval to market its human growth hormone, Humatrope. **Page 5**

■ Growing activity in the field of science, technology, and society leads to plans for an organization devoted to the field. **Page 6**

■ Occupational Safety & Health Administration begins takeover of California's job safety and health program, which was deleted from the state's budget by the governor. **Page 6**

Cover: Technicians at Sikorsky manufacturing facility oversee production of helicopter rotor blade made of hybrid composite of Kevlar and graphite fibers. Photo courtesy of Du Pont

Letters **2**

Concentrates

Business **14**

Government **19**

Science/Technology **23**

The Departments

ACS Comment **31**

ACS News **31**

Awards **32**

Newscrips **48**

Business

More chemical firms restrict smoking in their offices, reacting to laws on nonsmokers' rights, reports of passive smoking hazards. **Page 16**

Alternative Materials Institute is formed by manufacturers of materials that replace carcinogenic asbestos fiber. **Page 17**

International Business

Continued strong chemical growth in developing countries is attributed to lower prices for crude oil and other industry feedstocks. **Page 18**

Government

Congressional committees and subcommittees are busy reviewing many issues of interest to the chemical community. **Page 20**

Environmental groups file lawsuit over California governor's decision to list only 29 chemicals under state's new toxics control law. **Page 22**

Science

Modification of enzyme allows direct electrical communication between the enzyme and metal electrode. **Page 24**

Mytomyins combat cancer by forming crosslinks between adjacent strands of deoxyribonucleic acid. **Page 26**

Books

"Novations: Strategies for Career Management" identifies four distinct career stages and explains how they relate to advancement. **Page 28**



News Focus

The growth of advanced polymer composites is spurred by a wide variety of applications in products that were formerly made of more traditional materials, such as metals. **Page 7**

Wide Variety of Applications Spark Polymer Composites Growth

Advanced composites are one aspect of an evolving polymer composites universe that includes a heterogeneous mixture of materials, forms, and processes

Ward Worthy, C&EN Chicago

Question: What do the following items have in common: bowling lane, pressure cooker, canoe, and motor home?

Answer: Not much—except that they're all among the items that won product excellence awards at the Composites Show in Cincinnati last month. Needless to say, the four items were all made entirely or largely of "composites." Moreover, there were 36 other award winners in 11 different categories—plus many, many nonwinners.

The point is that composites—specifically, polymeric composites—are being used nowadays to make hundreds of types of products that formerly were the domain of more traditional materials, notably metals. The list includes airplanes, boats, auto parts, chemical process equipment, appliance cabinets, business machine housings, even caskets.

In many cases, composites can't compete with metals on a cost-per-pound basis. However, composite parts are often lighter than their metal counterparts, so fewer pounds are required. Also, the composites are inherently corrosion resistant and thus may last longer. Moreover, they present opportunities for savings through "parts consolidation." Often, a large complex part can be molded in one piece, whereas to make the corresponding part of metal would require the fabrication of many separate components that then would have to be assembled—an expensive process.

As is often the case with words, the word composite means different things to different people. In its broadest sense, a composite is simply a material containing more than one component. But to "materials people," the word has a narrower sense. They restrict its use to materials in which some type of reinforcement is embedded in some type of matrix. They also speak of synergy: The composite, desirably, has properties superior to the properties of its components taken separately.



Boat weighing 18% less than a typical boat of its size is made of nonwoven continuous glass fiber reinforcements

There are several kinds of composites, some with metal matrices, some with ceramic matrices, and some with matrices made of an organic polymer. With polymer-based composites (the subject of this article), the reinforcing fibers and fillers add tensile strength and stiffness. They often also improve dimensional stability—that is, they help reduce shrinkage during parts fabrication.

The polymer matrix does a lot more than hold the reinforcements together. It also plays the major role in determining such important matters as resistance to chemicals and weathering, thermal and electrical behavior, and appearance. Often it also adds toughness and impact resistance.

In addition to composites, there are "advanced composites." Although that term has lately attained buzzphrase status, its meaning is a little fuzzy, too.

Materials engineers define advanced composites quantitatively: modulus so much, moment of inertia so much, elongation-to-failure so much. Undoubtedly, their definitions are accurate, but they don't mean much to the uninitiated.

Price might be a good way to define them. Advanced composite systems based on thermoset resins currently cost about \$30 to \$60 a lb. Some of the newer advanced thermoplastic systems now under development cost \$100 to \$200 a lb. Amazingly, for some applications, they're worth it.

Perhaps the best definition: Advanced composites are composite materials that, by virtue of their outstanding strength-to-weight properties, make it possible to do things that otherwise couldn't be done.

For instance, Bryan Allen wouldn't have been able to pedal Paul MacCready's Gossamer Albatross across the English Channel in 1979. Similarly, Dick Rutan and Jeana Yeager wouldn't have been able to fly their Voyager nonstop around the world last December. Both aircraft, each a pioneer in its own way, owed much of their success to the strong, lightweight advanced composites that made up most of their airframes.

Looking ahead, a project that excites the advanced composites community is the Air Force's advanced tactical fighter (ATF) program. Two teams—one consisting of Lockheed, General Dynamics, and Boeing, the other of Northrop and McDonnell—are competing to build prototypes. According to John Wanamaker, a materials and process group engineer with Lockheed, probably about 50% of the ATF's structural weight will be composite materials, compared to less than 10% in today's fighter planes.

Not only are composites thus evolving technologically, they also make up a growth industry. The latter conclusion is borne out by figures compiled recently by the Composites Institute, an arm of the Society of the Plastics Industry.

Overall, shipments of composites in 1986 came to a record 2.28 billion lb, a 2.8% increase from 1985's 2.2 billion lb. For 1987, shipments are projected to grow another 3.0%, to nearly 2.35 billion lb (C&EN, Feb. 9, page 5).

Carl Rue, general chairman of the institute, notes that most segments of the composites industry have been growing faster than the economy as a whole. And that above-average growth rate, he says, appears likely to go on.

Rue, who is also vice president of sales and marketing for CertainTeed Corp. (a manufacturer of glass fiber for reinforcements), points to the auto industry—the largest single market for composites—as an example. Although U.S. auto production in 1986 fell 3.7% from the 1985 level, composites shipments to the industry rose 3.0% from 1985 levels, to 585 million lb. This year, auto production is expected to fall again. Even so, composites consumption is expected to increase another 4.0%, to 608 million lb. Furthermore, Rue says, the average composite content per vehicle will grow from 50 lb today to 61 lb by 1991.

The aircraft/aerospace/military market for composites is small, in terms of pounds, but it grew a whopping

12% in 1986, with shipments rising to 37 million lb. Another strong year is forecast for 1987, with shipments increasing 8.1% to 40 million lb. And they tend to be high-priced pounds, thanks to a large proportion of advanced composites.

Among the large-poundage markets, the construction industry is the second largest user (after autos). Shipments to that market totaled 456 million lb in 1986, a 2.7% increase from 1985. This year, Rue says, housing starts likely will drop. Nevertheless, he sees a 1.8% increase to 464 million lb.

In the marine market, composites shipments totaled 340 million lb, up 3.0% from 1985. In 1987, shipments are expected to grow another 3.2%, to 351 million lb.

After a flat 1985, composites use in the electric/electronics market rebounded in 1986. Shipments were up 5.8%, to 201 million lb. Growth will continue this year, with shipments expected to rise another 3.5% to 208 million lb.

Longer term, the outlook for composites is also rosy. According to a recent market analysis made by Kenneth E. Jacobson, a senior consultant with consulting firm Charles H. Kline & Co., sales of composites to certain specialty markets will grow from \$2.5 billion in 1986 to more than \$3.7 billion in 1991. That translates to an average annual increase of 8%, compounded.

The Kline study divides the market into different categories from those used by SPI's Composites Institute in its report of shipments. The former includes filled as well as reinforced composites; the latter includes primarily reinforced composites. Conversely, Jacobson points out, the study omits such major markets as construction and corrosion-resistant equipment, whereas the Composites Institute figures include those markets. Nevertheless, the conclusions reached by the two reports are generally in agreement.

For example, "automotive applications" accounted for about \$850 million, or 34% of the total, of composite sales in 1986. The market will grow 7% a year, reaching \$1.2 billion annually by 1991, the Kline study says. Electronics applications amounted to about \$750 million, or 30% of the total, in 1986. That market is expected to grow 9% a year, to just under \$1.2 billion annually by 1991.

The "other transportation" category, which includes aerospace, marine, and truck applications, will be the fastest-growing market of all. According to the Kline study, that market, which amounted to about \$425 million in 1986, will grow an average 13% annually over the next five years, reaching about \$780 million by 1991.

Anthony J. Cardinal, Du Pont vice president for textile fibers, is looking even farther ahead: "We see composites as a major growth market, with an annual value of about \$10 billion by the late 1990s." He adds that Du Pont intends to concentrate its own efforts on advanced composites, where, he says, consumption has been increasing at an annual rate of 30% for the past decade.

To describe the world of composites and some of the shifts taking place in its evolution is to describe a

universe of heterogeneous complexity. A multitude of components—resins, reinforcements, and additives—go into composites. The composite raw materials can take a wide variety of forms. And many differing processes are used to fabricate the materials into parts.

A list of all the resins that can be used to make composites is, for all practical purposes, a list of all resins. Not surprisingly, however, some resins are used more than others.

For example, in the Kline study of composites in specialty markets, total consumption of filled and reinforced plastics came to 2.4 billion lb in 1986. Of that, thermoset resin-based composites accounted for about 1.5 billion lb (62.5%) and thermoplastic resin-based composites for 900 million lb (37.5%).

Among the thermosets, polyesters were first, with about 60% of the total, followed by phenolics with 16% and epoxies with 15% of the total. "Others" accounted for the remaining 9%. Of the thermoplastics, polypropylene ranked first, with 44% of the total, followed by nylons with 26% and thermoplastic polyesters with 14%. "Others" accounted for the remaining 16%.

It's no accident that the thermoset polyesters have such a commanding lead. They offer a good balance of properties, are amenable to most fabrication processes, and are relatively inexpensive. Phenolics are more heat resistant and less flammable than polyesters, and they're also inexpensive. However, they're not so good cosmetically.

Epoxies, by virtue of their chemical and thermal resistance, strength, and dimensional stability, are usually the resins of choice for the so-called advanced composites. However, they're relatively slow-curing, and that characteristic limits their use in high-volume production applications. Polyurethanes, polyureas, polyisocyanurates, and related thermoset polymers are

widely used in reinforced reaction injection molding (RRIM) and resin transfer molding (RTM). Among the newer thermoset resins, vinyl esters are related to both epoxies and polyesters. They're said to provide the toughness and corrosion resistance of the former and the processing ease of the latter.

"Hybrid resins" are now being made, using a two-step process. First, a hydroxyl-terminated unsaturated isophthalate polyester is synthesized. That polymer is then reacted with a diisocyanate and styrene. The resulting hybrids are said to be tougher than polyesters and stronger, stiffer, and less expensive than polyurethanes.

A somewhat related approach involves the creation of an "interpenetrating polymer network" (IPN), in which two or more polymers are synthesized in the immediate presence of one another. The goal, again, is a product whose properties are superior to those of its individual components. For example, an acrylic-isocyanate IPN is said to provide exceptional resistance to moisture and high temperatures.

At the high-performance end of the spectrum are polyimides and bis-maleimides. They are among the few thermoset resins that provide the high strength, stiffness, and particularly the heat resistance required for advanced composites applications.

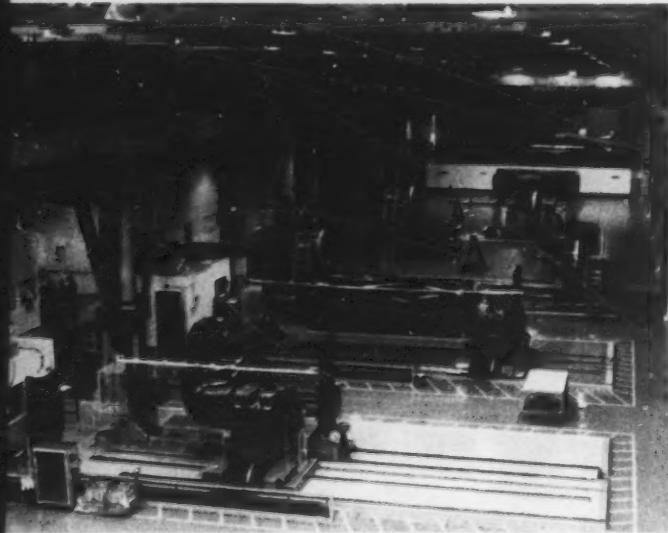
Although the thermosets have a substantial head start in the composites race, the thermoplastics are moving up fast. Their performance is in many cases as good as that of thermosets, and they offer some advantages in terms of handling and fabrication. For one thing, cycle times can be shorter, a decided advantage in high-volume applications. Also, if a part made of a thermoset composite is somehow botched during fabrication, it's usually just scrap. In contrast, a part made of a thermoplastic composite often can be remelted and reformed. That's especially desirable with the high-priced resins and fibers used for advanced composites.

Polypropylenes, the volume leader among the thermoplastics, probably would get more respect if they cost more. As it is, they offer, at a relatively low price, a good balance of properties, light weight, and exceptional resistance to flexing and impact.

Nylons and thermoplastic polyesters can compete with many of the thermosets in terms of electrical, dimensional, and thermal characteristics. They also tend to be more impact-resistant than the thermosets, and they're easier to fabricate. Acetals, fluoropolymers, polycarbonates, polyphenylene oxide, styrenic copolymers, and vinyls are among the other resins that have found one or more niches in the world of engineering thermoplastics.

In addition, several relatively new thermoplastic resins with outstanding mechanical and thermal properties are competing for the high end of the advanced composites market. The candidates include polyamide-imides, polyetherimides, polyetherether ketones, polyphenylene and polyarylene sulfides, and polyether sulfones.

Just as any of many resins may be used to form the matrix of a composite, so may any of a host of materi-



Hercules' aerospace division facility in Clearfield, Utah, applies filament winding for advanced composites to make missile engine cases

als be used to fill or reinforce the matrix. A corollary: just as a composite may contain more than one type of resin, so may it contain more than one type of filler or reinforcement.

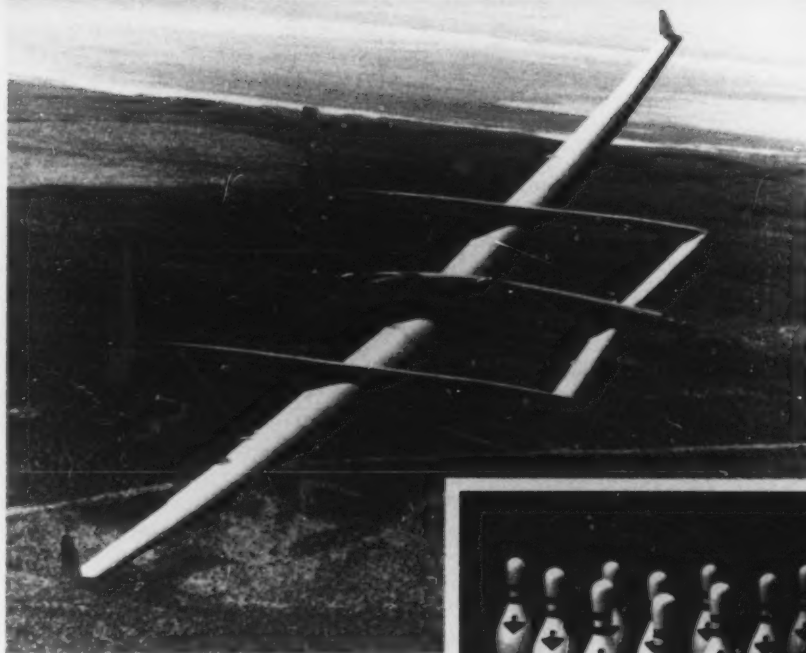
Composites may be of several major types, generally described as filled, laminar ("sandwich"), fiber-reinforced, or as combinations thereof. In fact, the categories don't break down that nicely, there being a sort of continuum. Generally speaking, the greater the aspect (length to diameter) ratio of the filler or fiber, the greater the reinforcing effect, in terms of increased tensile strength and stiffness. That is, flakes provide more reinforcement than spherical particles. Short fibers yield stronger products than flakes. Composites reinforced with long fibers are stronger than those reinforced with short fibers. "Advanced" composites typically are reinforced with continuous lengths of high-strength fibers.

In the case of fiber-reinforced composites, the arrangement of the fibers also affects the strength. If all the fibers point in one direction, the composite is strongest in that direction. If fibers are arranged with some at an angle to the others (as in a woven fabric), the strength is apportioned in both directions. If the fiber arrangement is random or multidirectional, the part tends to be about equally strong in all directions. Obviously, the choice of arrangements would be determined by the properties desired. "Put the fibers where the loads are" is the general rule.

There are two other important rules for fiber composites, according to industry consultant Gerald D. Shook. One, the modulus of the fiber should be greater than the modulus of the matrix. Two, the elongation of the fiber should be less than the elongation of the matrix. Shook uses this analogy to explain the rules: "You don't reinforce concrete with rubber hose."

Hundreds of different materials are used as fillers for composites. Talc, calcium carbonate, kaolin, wood flour, and mica are a few of the more widely used. One major reason for using fillers is to reduce costs. Generally, the fillers are a lot cheaper than the resins they extend. The fillers may even be air or other gases, as in the case of structural foams.

That doesn't mean that the fillers degrade the product, however. They can also add many useful properties. For example, they can increase its compression strength (just as sand and gravel increase the compression strength of concrete). They can improve the thermal and electrical properties of the composite. Or they can increase its dimensional stability. In the case of composites filled with flaky materials (like mica), with aspect ratios of the order of 25- or 50-to-1, the fillers also make a modest contribution to tensile



Variety of applications of polymeric composites includes Voyager aircraft, auto front end, satellite tracking antenna, and bowling lane surface



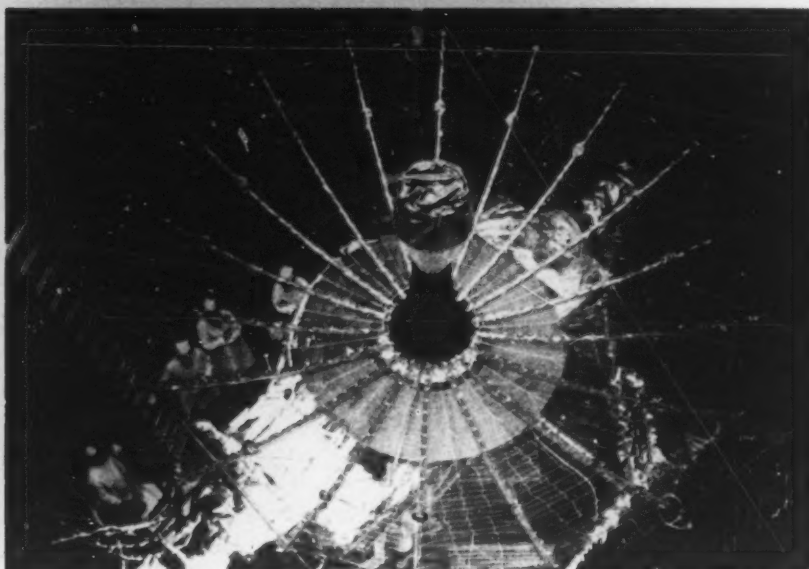
strength and stiffness as well.

In common parlance, the term "reinforced plastics" usually refers to products consisting of resin matrices stiffened and strengthened by the addition of fibers. Such everyday items as sisal and cotton fibers and fabrics, and even paper, find application as "crack stoppers."

However, the real workhorse among the reinforcing fibers is undeniably the borosilicate glass fiber known as "E-glass." It provides an excellent balance of properties at reasonable cost. It's been available commercially for more than half a century. And a great deal of technology has formed around it. A number of makers provide it in a variety of lengths and forms: chopped or milled short fibers, rovings (bundles of parallel strands—sort of untwisted yarn or rope), mats, woven or knitted fabrics, and others.

Although E-glass is the predominant reinforcing fiber, it isn't the only one. For example, polymers can form not only the matrix of a composite but also the reinforcing fibers. Special high-strength grades of polyester and nylon 6 fibers are offered for that purpose, for use either alone or together with glass fibers. Compared with glass, the thermoplastic fibers are lighter, less brittle, and tougher. According to Allied-Signal, it is currently the only U.S. firm supplying these fibers in forms specifically engineered for composite reinforcement.

In addition, several "high-performance" fibers have



been developed in recent years (C&EN, Feb. 2, page 9). These fibers have properties that set them apart from the rest. In particular, they have outstanding strength-to-weight characteristics and/or high resistance to heat and chemical attack.

Although the high-performance fibers weren't necessarily developed to reinforce composites, a number of them are being used for that purpose, either experimentally or commercially. Currently, these fibers are quite expensive, so that their use is largely restricted to the advanced composites.

Carbon (graphite) fibers, Owens Corning's S2-glass fibers, and Du Pont's Kevlar aramid fibers are the fibers now most widely used for advanced composites. Spectra fiber, an extended-chain polyethylene fiber developed by Allied-Signal, is a relative newcomer to the composites scene. Generally, the carbon and glass fibers have the edge in terms of stiffness and heat resistance, whereas the polymer fibers excel in terms of light weight and toughness. In some applications, both types may be used together to provide an optimum balance of properties.

Resins and reinforcements may be the two main components of composites. But there can be and generally is more to a composite than just those two.

Among other constituents that, depending on needs, may or may not be included in a given composite: accelerators, binders, flame retardants, flexibilizers, inhibitors, low-profile agents, low-shrink agents, mold release agents, pigments, sizings, suppressants, thickeners, thixotropes, ultraviolet absorbers, and wetting agents.

In other words, composites can be complicated. But many of the people who make things out of composites don't want to be in the formulation business. They want to buy a product that they can put in their machines and fabricate and that will do what it is supposed to do. Consequently, the putting together and selling of composite "systems" is a business unto itself.

Just as there are many resins and reinforcements available, so are there many different composite "compounds." In many instances, they're designed to use with specific fabrication processes, or to meet specific product requirements. For example, the resin-to-fiber ratio can be varied over a fairly wide range.

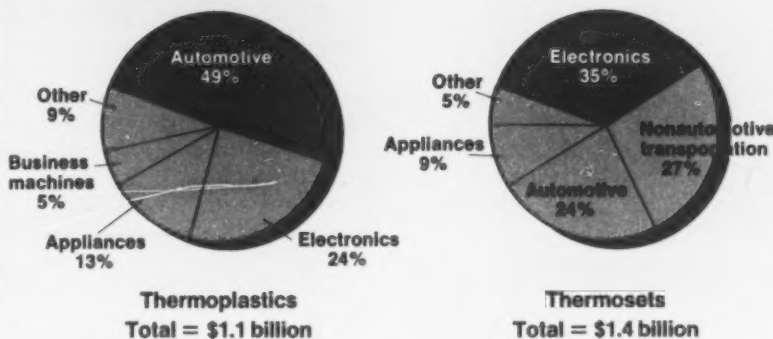
One type of compound is the "prepreg," which is short for "product made by preimpregnating woven or continuous reinforcement fibers with resins." Prepregs can be made with either thermoset or thermoplastic resins. And the prepreg may also include one or several additives.

Thermoset prepregs are brought to a relatively dry condition by partial curing. The final cure takes place during fabrication, with the application of additional heat. Carbon/epoxy and aramid/epoxy prepregs are often used for advanced composite applications. Some thermoset prepregs need to be refrigerated during shipment and storage, to prevent premature curing. Thermoplastic prepregs don't.

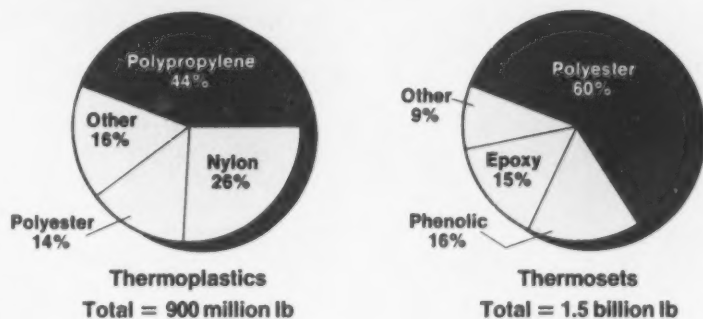
Sheet molding compound (SMC) is used for a variety of flat, thin parts (like auto body panels and appliance cabinets). To make it, chopped fibers, thermoset resin, fillers, and additives are spread on a film of polyethylene. A second polyethylene film is placed on top. This "sandwich" is kneaded to mix the components, pressed into a sheet about 1/4 inch thick, and then wound into a roll.

There are variations on the SMC theme. Thick molding compound, for example, is similar to SMC, but thicker (up to 2 inches). It's too thick to wind into rolls, so it's usually cut into slabs of appropriate size. Another variation, unidirectional SMC, incorporates continuous as well as chopped roving and thus provides greater directional strength and stiffness. Thermoplastic sheets can be made by a melt lamination process, using either chopped strand or continuous strand mats.

Auto and electronics industries are biggest markets for composites . . .



. . . and polypropylene and polyester are most widely used resins



Note: Consumption of filled and reinforced plastics in specialty markets, 1986. Source: Charles H. Kline & Co.

Bulk molding compound (BMC) combines short fibers, resins, and additives into a doughy material. It may be furnished in bulk, as the name suggests, or it may be extruded into "logs" for easier handling. One purveyor notes that BMC is used "where fine finish, good dimensional stability, part complexity, and good overall mechanical properties are important."

Many short-fiber compounds are furnished in pellet form for injection molding applications. These may be based on either thermoset or thermoplastic resins. And, like the other types of compound, they may contain a variety of additives, including lubricants to ease their passage into the mold.

As the variety of composite systems suggests, there are many processes that may be used to turn the materials into finished parts.

Perhaps the simplest of the processes is hand layup. Reinforcing fibers are arranged in a mold, a thermoset resin is poured over the fibers, and the mixture is pressed into shape with rollers. Then the setup is left alone while the resin cures, usually at room temperature.

The sprayup process is similar to hand layup, except that a special type of spray gun chops the fiber

and mixes it with the resin, then sprays the mixture into the mold. The sprayup approach allows more complexly shaped parts to be molded than does hand layup.

With both of these open mold processes, it's common practice, for the sake of appearance, to apply a resin-rich, pigmented "gel coat" to the mold before applying the main resin-fiber mixture. Both processes are best suited for low- to medium-volume production of large parts, including such things as boats, tanks, and building panels. Both processes provide only one finished surface. Equipment costs are relatively low, but skilled operators are essential to success.

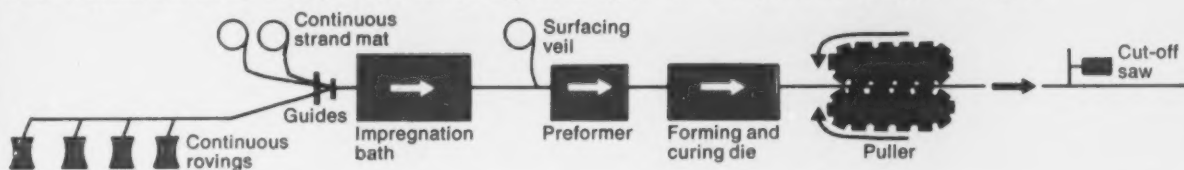
For slightly higher production rates, and for situations where two finished surfaces are required, a number of low-pressure closed molding processes are available. The simplest of these is cold press molding, which is a lot like the open molding processes except that the mold has a top as well as a bottom.

With resin transfer molding (RTM), the reinforcement is placed in the bottom half of a two-part mold and the mold is closed. Then the resin is pumped in. Reinforced reaction injection molding (RRIM) is similar, except that separate streams of chemicals are pumped into the mold, where the polymerization reaction then takes place. To make "structural" RRIM parts, long-fiber reinforcements are arranged in the mold before the liquids are pumped in, much as with RTM. For less demanding applications, flakes or milled fibers can be mixed with one of the liquid streams before it's pumped into the mold.

Compression molding processes are usually called for where high-volume production is involved. Or to put it another way, equipment costs are so much higher for these processes that high volumes are necessary to justify them. However, labor costs are substantially lower. The methods are suitable for thermoset composites (often using sheet or bulk molding compounds) and also for thermoplastic composites. In contrast to the open-mold and low-pressure closed-mold processes, external heat is added to hasten curing of thermosets, or to soften or melt thermoplastics so they will flow into the mold.

Injection molding processes can produce large numbers of complex parts reinforced with fillers or short fibers. The techniques can be used with either thermoset or thermoplastic resin systems, but with modifications. For thermoplastics, the injection chamber must be hot and the mold cool. For thermosets,

Pultrusion enables continuous molding of simple or complex structural shapes



however, the injection chamber must be cool and the mold hot.

High-volume fabrication processes such as injection molding are suitable only for use with short fibers. Conversely, only the relatively slow techniques requiring manual arrangement of the fibers are suitable for products reinforced with long continuous fibers.

Yet how advanced the composites are depends in large part on the fact that they employ continuous fibers oriented to afford maximum strength and stiffness. Indeed, a shortage of suitable fabrication techniques has hindered the broader use of ad-

vanced composites, especially in cost-conscious mass production industries like the auto industry.

According to J. Michael Bowman, director of Du Pont's composites division, fabrication is the "Achilles' heel" of advanced composites. Even for the most demanding aerospace and military applications, he points out, the advanced composite materials often must be formed into parts with essentially the same hand layup techniques that are used to make boats.

The process is further complicated by the fact that the resins used in these systems cure at high temperatures, so that the parts must be autoclaved. Consequently, development of fast, automated production techniques for advanced composites has a high priority.

However, two fairly well-automated processes now in use are specifically designed for continuous fibers. One of these processes is filament winding. Continuous lengths of strand or roving are impregnated with resin, then wound onto a rotating mandrel in a pattern calculated to provide maximum strength where it's needed. The process is used to make hollow, more or less cylindrical parts like chemical storage tanks, pipes, rocket motor cases, helicopter rotor blades, and automotive drive shafts.

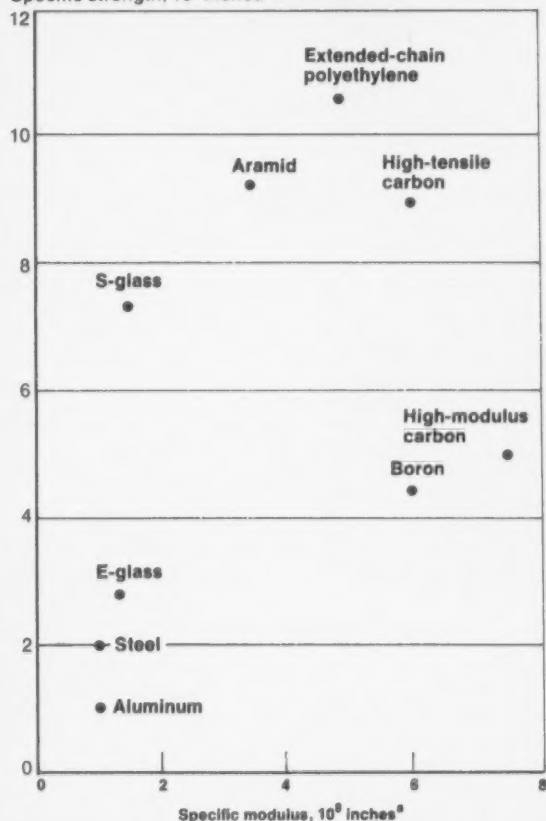
The other long-fiber process is known as pultrusion. As the name suggests, pultrusion is a combination of extrusion and pulling. Rovings, continuous strand mat, tapes, or other appropriate reinforcements are pulled through tanks of thermoset resins, through a preformer, and then through a die, where the product is formed into its final shape and cured by heating. The process is used for the continuous manufacture of a variety of structural shapes—including complex ones—of constant cross section: beams, pipes, bars, rails, and such.

Finally, just as development of fabrication processes for composites has lagged behind the development of materials, so has the science of composites lagged behind the technology of composites. Much more is known than is understood.

Some progress is being made, however, in industry as well as in academia. For example, organizations devoted to basic research in composites have been established at several universities. Probably the best known is the University of Delaware Center for Composite Materials, founded in 1974. Similar centers have been established at other schools, including Virginia Polytechnic Institute, Purdue, and Rensselaer Polytechnic Institute. Generally, funds to support these activities are furnished by the composites industry, by the National Science Foundation, and by other government agencies with an interest in composites. □

High-performance reinforcing fibers have good strength-to-weight properties

Specific strength, 10^6 inches²



Note: Values are representative. • Strength or modulus divided by density.

MARCH 23, 1987

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NEWS

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Page 23

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News of the Week

■ **Occupational Safety & Health Administration is scheduled to hold hearings on proposed regulations for lab worker safety.** Page 4

■ **NL Chemicals sues United Catalysts over alleged infringement of dispersant patents and the misappropriation of confidential information.** Page 5

■ **Report on U.S. energy supply and its role in national security urges U.S. to reduce dependence on oil imports.** Page 5

■ **Bayer is sued by hemophiliacs who claim they acquired AIDS from taking Factor VIII, an antihemophilia drug.** Page 6

■ **In effort to combat acid rain, President Reagan announces he will seek \$2.5 billion to develop clean-coal technologies.** Page 6

News Focus

National Science Foundation's Erich Bloch discusses the problems that face NSF, its changing role, and its outlook. Page 7

Business

Chemical industry R&D funding will increase this year, but at a slower rate than last year, according to NSF survey. Page 15

International Business

Japan's chemical industry weathers recession triggered by stronger yen, foresees more profitable times. Page 16

Government

Department of Defense is urged to strengthen defense technology base through more university research funding, industry incentives. Page 18

Science

NASA's supercomputer system, considered the world's most advanced and powerful, begins operating. Page 21

Books

"The Biotechnological Challenge" examines the role and future of biotechnology in Third World countries. Page 77

Cover: Photo by C&EN's James H. Krieger

Letters 2

Concentrates

Business 13

Government 17

Science/Technology 20

The Departments

New Products 58

ACS Comment 80

ACS News 83

People 86

Newsletters 102



Instrumentation '87

The Pittsburgh Conference, a showcase for developments in analytical chemistry and spectroscopy, offers a look at the newest hardware and software. Page 23

Growth in Chemical R&D Funding Slowing

In its annual survey of corporate research and development budgets, the National Science Foundation projects another increase for all U.S. industry and for the chemical industry in 1987—albeit a slowdown for both from 1986's growth. However, unlike last year, it predicts that growth in chemical industry R&D funding will outpace the industry average.

Total industrial R&D spending this year will increase 4.9% from 1986 to a total of about \$59.5 billion, according to the survey. For chemicals and allied products, R&D spending will rise 5.5% to about \$9.6 billion.

The growth forecast for all industry represents quite a slowdown from last year's 6.6% growth from 1985. According to NSF, one of the reasons cited by those surveyed for the slower growth is uncertainty about business conditions. "For the second year in a row, company officials expressed great uncertainty about business conditions for the coming year and were hesitant to forecast a firm 1987 R&D growth figure based on their current preliminary budget plans," the report says.

NSF points out that although R&D officials noted a relatively healthy economy, a number of factors—including lack of capital investment despite low interest rates, concern

over profitability, and their companies' involvement in takeovers, mergers, and reorganizations—made it unusually difficult to make final plans for this year's R&D activities.

Despite its better-than-average 5.5% growth, the chemical industry will be outpaced in R&D spending growth this year by three major industry sectors: electrical equipment (8.7% to \$12.5 billion), professional and scientific instruments (6.0% to \$5.3 billion), and machinery (5.9% to \$10.8 billion). Industry sectors lagging the chemical industry's growth rate will be aircraft (4.5% to \$4.6 billion), motor vehicles and motor vehicle equipment (no growth at \$6.6 billion), and all other industries combined (1.0% to \$10.0 billion).

Last year, when the chemical industry's growth in R&D spending (5.8% to \$9.1 billion) lagged the 6.6% average increase for all U.S. industry, there was a similar mix of sectors that outpaced and trailed the chemical industry. Those whose R&D funding grew more than for chemicals were electrical equipment (11% to \$11.5 billion), motor vehicles and motor vehicle equipment (8.2% to \$6.6 billion), and machinery (7.4% to \$10.2 billion). Those sectors trailing chemical industry growth were aircraft (4.8% to \$4.4 billion), professional and scientific equipment (4.2% to \$5.0 billion),

and all others (3.1% to \$9.9 billion).

The NSF survey falls much in line with C&EN's own survey of R&D spending by 12 major chemical companies (C&EN, Jan. 19, page 11). The C&EN survey projects that chemical R&D spending will rise about 4% this year, but that the growth will be down substantially from 7% last year. However, the NSF survey includes more of the specialty chemical and pharmaceutical industries, both high R&D spenders, than does the C&EN survey.

NSF finds that for industrial chemicals, R&D spending will rise about 3% in 1987, the same percentage as in 1986. NSF says that companies are cutting back on R&D spending on maturing products and concentrating instead on newer industrial specialties such as chemicals for the electronics industry and on engineering plastics. These companies, NSF says, are also active in biotechnology, plant biology, and animal science.

One of the changes noted by the survey is the relationship between R&D spending and the number of R&D professionals employed. In the 1970s, NSF notes, data showed a high correlation between real-dollar changes in R&D spending and annual changes in the number of full-time-equivalent R&D scientists and engineers employed by industry. Such employment is the sum of the number of scientists and engineers employed full time in R&D plus the full time equivalent of those working part time in R&D.

Since 1982, R&D spending in constant dollars has been increasing at a somewhat faster rate than the rise in full-time-equivalent employment of R&D scientists and engineers. Many R&D managers say that their increased budgets are being spent on advanced technological equipment and instrumentation systems.

William Storck, New York

Chemical industry R&D spending to rise 5.5% this year

\$ Billions	1987 projected	1986 projected	1985	% annual change 1987	1986
Chemicals and allied products	\$ 9.6	\$ 9.1	\$ 8.6	5.5%	5.8%
Machinery	10.8	10.2	9.5	5.9	7.4
Electrical equipment	12.5	11.5	10.4	8.7	10.6
Motor vehicles and motor vehicle equipment	6.6	6.6	6.1	0.0	8.2
Aircraft	4.6	4.4	4.2	4.5	4.8
Professional and scientific instruments	5.3	5.0	4.8	6.0	4.2
All others	10.0	9.9	9.6	1.0	3.1
TOTAL*	\$59.5	\$58.7	\$53.2	4.9%	6.6%

* Does not add because of rounding. Source: National Science Foundation

MARCH 30, 1987

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CHEMICAL & ENGINEERING

NEWS



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CHEMICAL OSCILLATIONS

Patterns in space and time
Page 24

News of the Week

■ **National Academy of Sciences begins series of seminars on research at forefront of technology, engineering, and science.** Page 4

■ **Discovery of first ferromagnetic organic polymers is reported by U.S. and Soviet research groups.** Page 5

■ **British Petroleum, already a 55% owner, announces plans to acquire remaining 45% of Standard Oil.** Page 5

■ **Strong rise in chemical company stock prices during first three months of 1987 reflects stock market surge.** Page 5

■ **FDA plans to speed up approval process of some drugs that are used for terminal diseases.** Page 6

Cover: Bull's-eye patterns in petri dish are formed by the oscillating chemical activity of a thin layer of Belousov-Zhabotinskii reactants. Photo by Arthur T. Winfree, University of Arizona

Letters 2

Concentrates

Business 7

Government 12

Science/Technology 16

The Departments

Meetings 40

ACS News 46

Newscrips 56

Business

Decline in value of U.S. dollar has not helped the chemical industry fight foreign competition as had been expected. Page 9

Fine chemicals industry remains healthy as it adapts to changes in pharmaceuticals—a major market—and in other fields. Page 10

Government

Worker risk notification bills raise problems including how notification process should be implemented, extent of legal ramifications. Page 13

Recent progress in chemical weapons negotiations renews hopes for a treaty, but French decision sparks new concerns. Page 15

Education

Third World scientists will get advanced training in biotechnology methods in six-week program offered by West German institute. Page 17

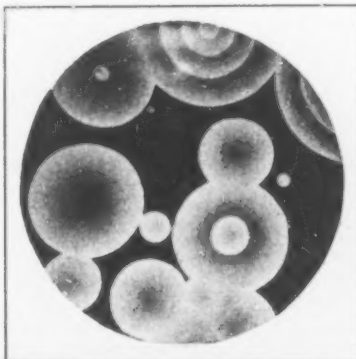
Technology

New elemental analyzers, portable electroanalyzer, and spinning band distillation column are described at Pittsburgh Conference. Page 20

Immunoassay technology for quantitative analysis of organic compounds is being developed by Westinghouse Bio-Analytic Systems. Page 22

Books

"Hazardous Waste Management: Reducing the Risk" offers guidelines for evaluating disposal sites. Page 37



Special Report

Despite both experimental and theoretical evidence for the existence of chemical oscillations in time and space, only recently have they evolved into a major field of chemical research. Page 24

First ferromagnetic organic polymers prepared

Two independent research groups in the Soviet Union and U.S. just published accounts of the discovery of the first organic polymers that spontaneously become magnetic at ambient temperatures. This property, known as ferromagnetism, results when the spins of unpaired electrons in a material spontaneously orient themselves in the same direction, creating a bulk magnetic effect.

Ferromagnetism is the last entry on the list of electronic properties that once were thought to be restricted to inorganic materials but have now also been observed in organic materials. That list includes metallic conductors, semiconductors, and superconductors. Organic ferromagnets might one day replace metals or metallic compounds now used for their magnetic properties, such as chromium dioxide, which is used to coat magnetic recording tape.

The Soviet researchers, led by A. A. Ovchinnikov of Moscow's Institute of Chemical Physics, prepared their ferromagnetic material by polymerizing a stable biradical monomer consisting of a cyclic nitroxyl group attached to either end of a diacetylene fragment [*Nature*, 326, 370 (1987)]. The Soviets apparently were not able to control the degree of polymerization or the size of the polydiacetylene chains thus formed.

In a commentary in the same issue of *Nature*, Richard H. Friend of the University of Cambridge, U.K., points out that "only a small fraction (0.1%) of the monomer prepared by the Soviets is converted to ferromagnetic polymer, although this fraction can be magnetically separated from the residue." The polydiacetylene polymer remains ferromagnetic up to about 150 °C, a limit that Friend calls "respectably high." Above that temperature, the electron spins lose their alignment, leading to a loss of magnetism.

The Soviet work is significant, Friend says, because it shows that the electron spins of polymer-bound radicals can align along the length of the polymer chain. But, he adds, it is "far from ideal," because the yield of ferromagnetic material is

so low and the product is so poorly characterized.

The U.S. results, just published in *Synthetic Metals* [19, 709 (1987)], suffer from similar drawbacks. They were first announced in December 1984 at a scientific meeting by physicist Jerry B. Torrance of IBM Almaden Research Center in San Jose, Calif., and his coworkers. They have observed ferromagnetic behavior in a polymeric material produced by the reaction of 1,3,5-triaminobenzene with iodine. "The chemistry going on in this reaction is a real mess," Torrance says, and his group has not been able to characterize its material. The yield of ferromagnetic polymer in the reaction also is very small (at most 2%), and the product is "not very reproducible," he notes. Nevertheless, the material—when it is obtained—remains ferromagnetic to high temperatures, until it decomposes near 400 °C.

Both groups have established that their polymer's ferromagnetism is not due to any metallic impurities.

Despite the lack of high-yield, well-characterized products in the Soviet and American work, scientists expect these results "will certainly stimulate further efforts to synthesize other organic ferromagnets."

In related work during the past year or so, Du Pont chemist Joel S. Miller and his coworkers have been able to prepare crystalline, organometallic charge-transfer salts such as decamethylferrocenium tetracyanoethylene, which show reproducible ferromagnetism. However, unlike the aforementioned polymers, this particular salt, for instance, is a ferromagnet only at temperatures below 4.8 K. □

BP to acquire rest of Standard Oil

British Petroleum announced last week that it will make a tender offer to acquire all of the outstanding shares of Standard Oil Co. that it does not already own. The U.K. firm currently owns 55% of Ohio-based Standard Oil, which ranks 59th among U.S. chemical producers.

BP will offer \$70 per share in cash for the remaining 45% of Standard Oil, making the deal worth more than \$7 billion. Standard Oil's stock price the day before the announcement was \$64 $\frac{7}{8}$ per share. Thus the offer, which BP will make no later than April 1, represents a premium of about 8% for stockholders.

To finance part of the deal, BP is seeking loans for \$5 billion in the form of a revolving credit with a four-year term.

The combined firm will emerge as a moderate force in the U.S. chemical industry. BP's chemical sales figures in the U.S. are not available, but its BP North America subsidiary produces a number of polymers and specialty chemicals. Standard Oil's chemical sales in 1986 were \$1.1 billion, down 21% from 1985, but its operating earnings from chemicals increased 7.5% to \$57 million (excluding an extraordinary charge of \$14 million in 1985). □

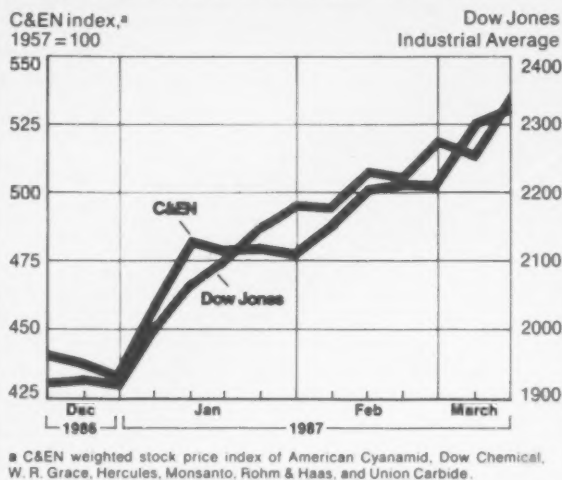
Chemical firms ride stock market surge

For the first three months of 1987, chemical company stock prices have performed just about as stunningly as the widely accepted stock market yardstick, the Dow Jones Industrial Average, which continued setting new records last week.

C&EN's chemical stock index—based on the weighted market value of stocks of American Cyanamid, Dow Chemical, W. R. Grace, Hercules, Monsanto, Rohm & Haas, and Union Carbide—increased 20.6% for the three-month period ending March 20, reaching a level of 532 (1957 = 100). That's essentially the same as the 21% growth in the Dow Jones Industrial Average over the same period, reaching 2333 on March 20. The chemical stock index outperformed the New York Stock Exchange Composite Index, which rose 18.7% during the period, and Standard and Poor's 500, which was up 19.4%.

Generally, however, the indexes of smaller stock activity outperformed the chemical stock index. The best performance was tallied

Chemical stocks reflect heady growth in major industrials over past three months



by the Over-the-Counter Industrials, which rose 31.5%, and the American Stock Exchange Index, which gained 27.3%. The Over-the-Counter Composite increased 24.8% and Standard & Poor's 400 Industrials rose 23.1%.

Growth in C&EN's chemical stock index, good as it has been in the first quarter, still lags that recorded in the most recent annual overview of chemical stock performance in July 1986. At that time, the chemical stock index had posted an annual 47.2% rise to 399 on July 18, compared with the Dow Jones Industrial Average, which rose 30.8% to 1778.

According to Shearson Lehman Brothers vice president and chemical industry analyst Theodore Semegran, recent chemical stock performance has benefited from continued strong chemical business, with particular strength in plastics and organic chemicals. Polypropylene and polyvinyl chloride sales have been particularly strong, he says, resulting in good market performances by three new companies whose stocks were listed on the New York Stock Exchange over the past three months: Aristech (up 63.4% since being issued and closing at \$29 per share on March 20), Himont (up 36.8% and closing at \$41 $\frac{3}{4}$ per share), and Vista (up 89% and closing at \$32 $\frac{1}{2}$ per share).

Of the companies in the C&EN

chemical stock index, Dow has been the best performer over the past three months, rising 35.2% to \$82 $\frac{1}{2}$ per share on March 20. Next is Union Carbide, gaining 28.8% to close at \$29 per share, and American Cyanamid, rising 21% to \$97 $\frac{3}{8}$ per share.

FDA plans to speed up some new drug approvals

After years of debate and controversy, the Food & Drug Administration is about to enter revolutionary new territory in speeding the approval of new drugs aimed at treatment of terminal diseases. The regulations, in effect, would combine the selling and testing of new clinical formulations for patients with life-threatening diseases such as acquired immune deficiency syndrome (AIDS) and cancer.

FDA announced its new proposals, called the "IND Rewrite," in the March 19 issue of the *Federal Register*. The proposals would place on "fast track" the Investigational New Drugs process, allowing physicians to prescribe promising but incompletely tested drugs for terminal diseases. INDs are those drugs for which companies seek FDA approval in order to begin clinical trials. In one sense, FDA scientists would work with industrial researchers as they develop and test the new drugs.

Chemical stock index keeps pace with most other indexes

	Dec. 19, 1986	March 20, 1987	% change
C&EN Chemical Stock Index	441	532	20.6%
Dow Jones Industrial Average	1928.85	2333.62	21.0
New York Stock Exchange Composite	142.65	169.37	18.7
American Stock Exchange Index	265.46	337.60	27.3
Over-the-Counter Composite	352.24	439.64	24.8
Over-the-Counter Industrials	351.80	462.79	31.5
Standard & Poor's 500	249.73	298.17	19.4
Standard & Poor's 400 Industrials	277.90	341.99	23.1

The four other companies making up the chemical index had below-average increases, with Grace up 19.1% to \$62 $\frac{1}{4}$ per share, Rohm & Haas up 18.3% to \$43 $\frac{3}{8}$ per share, Hercules up 13.1% to \$60 $\frac{1}{2}$ per share, and Monsanto down 0.3% to \$78 $\frac{1}{4}$ per share. □

Drug companies haven't come to any consensus about the proposal yet and were meeting last week at the Pharmaceutical Manufacturers Association in Washington, D.C., to develop one. But a major consumer group has long since been up in arms. "These new regulations," says Sidney M. Wolfe, director of the Public Citizen Health Research Group in Washington, "represent a gross decrease in the conditions necessary to distribute these drugs. It is an open invitation for companies to sell drugs that don't have good evidence of safety and efficacy. There are enough charlatans exploiting AIDS patients as it is."

Wolfe says FDA's approval for the sale of azidothymidine (AZT) on March 20 was the model that should be followed. "That was a closed clinical trial," he says. "It involved controlled studies, then distribution. FDA wants to go way beyond this and let these new drugs out loose and jeopardize already sick people." □

Weaker Dollar Hasn't Helped Chemical Trade

That's because much U.S. chemical trade involves countries where the dollar value has remained steady or has grown stronger

The value of the U.S. dollar has fallen dramatically against some major foreign currencies over the past two years. But that drop has not helped the U.S. chemical industry so much as expected.

In fact, the weakening dollar has helped very few U.S. industries, and what help it has provided has been very unevenly distributed among them. That's the conclusion of a study made by Claremont Economics Institute (CEI), Claremont, Calif., on the impact of the declining dollar on various segments of U.S. industry.

CEI president Deborah Allen Olivier says that only a few specific industries will face less international competition as a result of the dollar's depreciation. Fewer still will benefit substantially. Within the chemical and related products sector, only pharmaceuticals will be one of those fortunate few.

Instead, says Olivier, most U.S. producers will actually face tougher foreign competition this year than they did over the past two years, despite the falling value of the dollar. Based on CEI's studies, this could be true for virtually every segment of the chemicals and allied products industry.

The dollar's decline has had a different impact on different industries in the U.S., CEI says, because the major international competition for one U.S. industry may not come from the same region or country as

that of another industry. Meanwhile, the dollar has fallen against only a handful of foreign currencies.

The dollar is down primarily against the Japanese yen and the major European currencies. The dollar's decline against those key currencies has attracted a lot of attention and publicity. Conventional wisdom holds that, as a result, the U.S. trade deficit will narrow and industrial production in the U.S. will increase this year.

CEI contends that those U.S. producers whose primary rivals are in Japan or Western Europe will, indeed, face less international competition this year. But for many U.S. industries, the major competition comes from countries such as Canada, Mexico, Brazil, South Korea, and Taiwan. And compared to the currencies of these countries, the dollar has not fallen, but has actually grown stronger. In some cases, the dollar has appreciated as much as 300% against some of those currencies in the past two years.

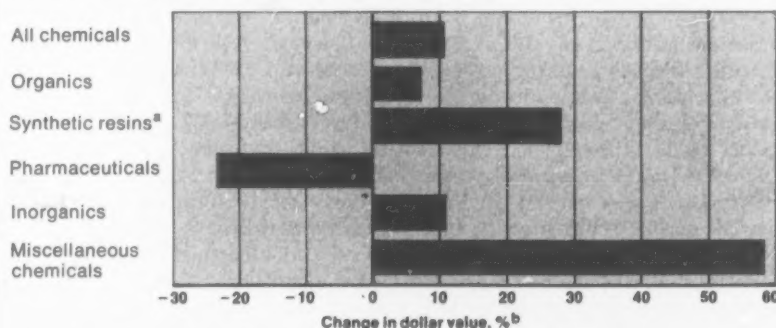
During the past two years (as of January 1987), the dollar's value has dropped about 45% against the Japanese yen, the Swiss franc, and the

German mark. It has dropped about 35% against other European currencies, and 30% against the British pound.

Some industry and government leaders seem to believe, says Olivier, that if U.S. industry has not been saved and the trade balance improved by now, then the dollar must simply go down some more against these currencies until U.S. producers gain the upper hand. But, as she also points out, over this same two-year period, the dollar has held steady against the Canadian dollar, the Korean won, and the Hong Kong and Singapore dollars. More important, it rose 370% against the Mexican peso, 300% against the Brazilian cruzado, 100% against the Venezuelan bolivar, and 15% against the Australian dollar.

Because many U.S. industrial and agricultural products compete more against goods produced in those countries than in Japan and Europe, Olivier argues that an additional decline of the dollar against the yen or European currencies will do "absolutely nothing to help most American producers." Among those it won't help are chemical producers.

The dollar hasn't grown "weaker" for many chemicals



^a Plastics and rubber. ^b Change in dollar's trade-weighted value from February 1985 to January 1987.
Source: Claremont Economics Institute

Mexico, Brazil help keep dollar's "value" up for chemicals

Trade-weighted % change in dollar^a

Country	All chemicals	Organics	Synthetic resins	Pharmaceuticals	Inorganics	Specialty chemicals
Australia	0.3%	nm	0.3%	0.5%	nm	0.7%
Belgium-Luxembourg	-1.7	-1.7%	-3.8	-1.3	-2.1%	-2.0
Brazil	8.1	12.3	8.8	nm	nm	28.8
Canada	0.1	0.1	0.1	nm	0.1	0.1
France	-2.3	-1.6	-1.8	-2.5	nm	nm
Hong Kong	nm	nm	-0.01	nm	-0.03	nm
India	nm	nm	1.2	nm	nm	nm
Italy	-1.0	-1.4	nm	-2.3	nm	nm
Japan	-4.9	-5.1	-2.8	-6.0	-4.1	-3.9
Mexico	20.0	15.1	33.6	nm	18.5	35.2
Netherlands	-2.3	-3.6	-3.0	-1.4	-4.5	-2.1
Singapore	nm	nm	nm	-0.2	nm	-0.2
South Korea	0.1	0.1	0.1	nm	0.1	nm
Spain	nm	-0.6	nm	-1.0	nm	nm
Switzerland	-0.9	-0.9	nm	-1.5	nm	nm
Taiwan	-0.2	-0.2	-0.2	nm	nm	nm
U.K.	-1.5	-2.2	-1.2	-1.7	nm	-1.3
Venezuela	nm	nm	2.2	nm	4.9	4.7
West Germany	-3.2	-3.6	-4.0	-4.3	-2.2	-2.1
TOTAL	10.5%	6.5%	27.5%	-23.7%	10.5%	57.7%

^a Change in trade-weighted value of the dollar from February 1985 to January 1987. "Trade-weighted share" is the actual percent change in the dollar times the product's percentage share of total trade. nm = not meaningful; only data approximating 75% of each sector's total were evaluated. Source: Cleveland Economics Institute

Economists generally focus on various "trade-weighted" measures of the U.S. dollar. The Federal Reserve Board index, which covers only 10 major countries, fell 39% since its early 1985 peak. Other indexes cover more countries. Generally, the more countries covered, the stronger the dollar has remained. The Dallas Federal Reserve Bank index covers 131 countries. It fell only 5%.

None of these indexes, however, tell which industries benefit, or suffer, or by how much. That is why CEI constructed a different dollar index for each specific product category. In each, the movements of the dollar against all of the various currencies are weighted by the actual proportions that each foreign country represents in that specific product trade with the U.S. In its study, CEI did not completely blanket the world, but its data cover at least 75% of U.S. trade (exports plus imports) for each product studied.

For instance, using 1985 data, Canada accounted for 15.5% of U.S. chemical trade. Japan accounted for 11.8%, and other countries each accounted for lesser shares. Apply-

ing these trade shares of each country to the dollar value change against that country's currency, CEI comes up with a trade-weighted "product-dollar" index.

For Canada, whose currency has changed little against the U.S. dollar over the past two years, the change in the "chemical-dollar" index is 0.1%. For Japan, whose yen has soared against the dollar, it is -4.9%.

By using this approach with all of the U.S.'s major chemical trading partners, CEI estimates that the U.S. chemical industry is 10.5% worse off now than it was two years ago, as far as the dollar is concerned. One reason that chemicals have not benefited much by the declining dollar is that 17.4% of U.S. chemical trade is with Canada and Australia, whose currencies have remained relatively weak against the dollar. Mexico and Brazil account for only 8% of U.S. chemical trade. But their inflation-wracked economies have made their currencies 370% and 300% weaker, respectively, against the dollar.

Earl Anderson, New York

Fine chemicals adjust to changing markets

The fine chemicals industry, to some extent, is a puzzle: What, precisely, is meant by "fine chemicals"? To the people in the business, however, it's no puzzle. They define fine chemicals as organic compounds, made by multistep syntheses, worth more than \$10 per kg. And it is, by and large, a healthy business. That's the assessment of Albert V. G. Hahn, senior adviser to Ecoplan International, Paris-based consultants, who has just completed a study on the fine chemicals industry.

The world market for fine chemicals in 1985 was about \$13.8 billion, and last year it probably topped \$14 billion. Nearly two thirds of that, 64%, is accounted for by pharmaceutical active compounds, and another 12% by pesticide active ingredients. Other markets, such as dye intermediates and flavors and fragrances are surprisingly small, but only because most of those compounds are priced at less than \$10 per kg.

More than half the world's capacity for fine chemicals is owned by major companies—chemical producers, such as Bayer and Hoechst, and large pharmaceutical companies for captive use. These companies, many of which are European, account for 58% of capacity.

The remaining 42% of global capacity accounted for by nonmajor companies comprises as many as 400 to 450 companies. Of these, European companies account for about half of the capacity. By type of company, about half the capacity is owned by small and medium-sized pharmaceutical companies, about 30% is owned by true independent firms, and 20% by separate units or divisions, with plants dedicated to fine chemical production within large multiproduct companies, the Ecoplan report says.

The study was designed to address the strategic concerns of the fine chemicals industry. With that charter, the company was able to do some wide-ranging analysis—for example, to identify the changes sweeping through the fine chemi-

cals business. Changes are always occurring in any business sector. However, according to Ecoplan, the fine chemicals business has entered a period of major structural change, mainly as a result of changes in the primary end-use field, pharmaceuticals.

"Since 64% of fine chemical markets is pharmaceuticals, you must look at changes there," Hahn says. "And the main force behind the change in that [market] is the slowdown in the introduction of new molecules."

That is having a profound impact on pharmaceutical active-ingredient producers who heretofore have made the profits from synthesizing patented products. With fewer new, patented synthetic molecules around, fewer people can make money. Moreover, as patents expire, an increasing number of products will become generic, and it will be more difficult for small, independent companies to survive, the report predicts. For survival, a company must be big, number one in its market, and integrated, according to the report.

"Five to 10 years ago," Hahn says, "if you had suggested to any major chemical company's management that they make a molecule that wasn't theirs, they would have been aghast. They would never do such a thing."

"They looked at 'pirates'—companies that would make generic

compounds, for example—with contempt. Now, they are becoming their own pirates. If it works, let's make it ourselves." Companies are more willing to market bulk products, even to their own competitors.

On the other hand, another option is to convince companies to "buy" rather than "make," or persuade them to buy advanced intermediates and leave only the final one or two steps to the formulator. The difficult steps—the hazardous or unpleasant chemistry, for example—are the early steps, and these are the domain of the fine chemicals producer.

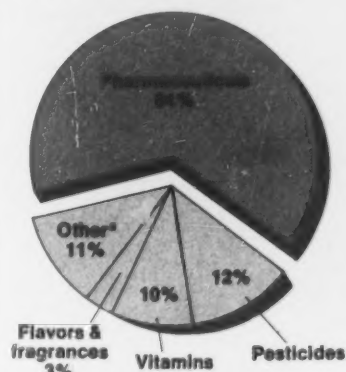
Other markets beyond pharmaceuticals are of growing interest to fine chemicals producers, too. One example is agricultural chemicals. "Until recently," Hahn says, "pesticide active ingredients were not fine chemicals, but really commodities selling for less than \$10 per kg. Now, some of them, such as the pyrethroids, systemic fungicides, and new generations of low-dosage herbicides, are increasingly within the range of fine chemicals."

Similarly, fine chemicals are beginning to find their way into plastics, both as comonomers for engineering plastics and as additives or intermediates for additives, the report says. "As service temperatures or impact strength requirements rise, so do the costs of monomers and additives," Hahn notes.

Increasingly, however, producers must balance the constraints of market demand and efficient production size. Large, in the fine chemicals business, is anything more than 200,000 L of reactor capacity. "That is a big plant, and the consensus is that a good fine chemicals plant starts at that," he says. On the other hand, a limitation is imposed by market size, and physical and economic risk.

Nonetheless, the trend is toward larger reactors. Many companies have ended up with reactors that are too small. When times were easy, the small reactors were satisfactory, but as competition increased, they became less attractive economically. The result, Hahn says, is that "acquisitions are a distinct possibility, especially beyond the Alps and the Pyrenees."

Pharmaceuticals take most fine chemicals demand



Total 1985 = \$13.8 billion

^a Includes specialty monomers and photochemicals. Source: Ecoplan International

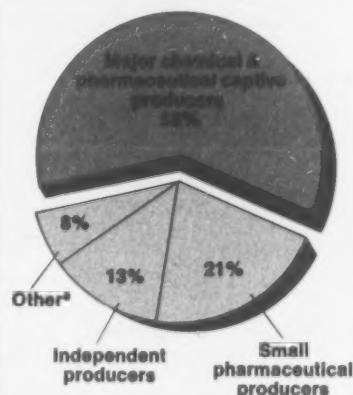
Ecoplan predicts real growth of about 2.5% per year in demand to the year 2000. "Some people think there will not be so much growth per se as opportunities in make vs. buy, or doing what they do now, but better." And he adds that some producers are skeptical about even that much growth.

However, Ecoplan is reasonably confident about the prospects for the fine chemicals business. Opportunities, for example, will arise from the increasing complexity of new molecules, because whatever is easy and obvious already has been screened. More complex means more difficult reactions—but higher product prices. And growth will characterize some of the more exotic fields, such as electronic chemicals and photo initiators, although the markets are small now.

What no one seems quite sure of is the impact that biotechnology will have on the industry. "Not all that much cross-fertilization seems to be happening," Hahn observes. But there are indications that companies at least want to keep up to date on what is happening. Biotechnology is already an important processing tool for chemicals, through fermentation, as extracts or animal products, and so on. How much more important it will become remains to be seen in this already complex and challenging business.

Patricia Layman, London

Major companies own most fine chemicals capacity



^a Separate units or divisions of multi-interest producers. Source: Ecoplan International

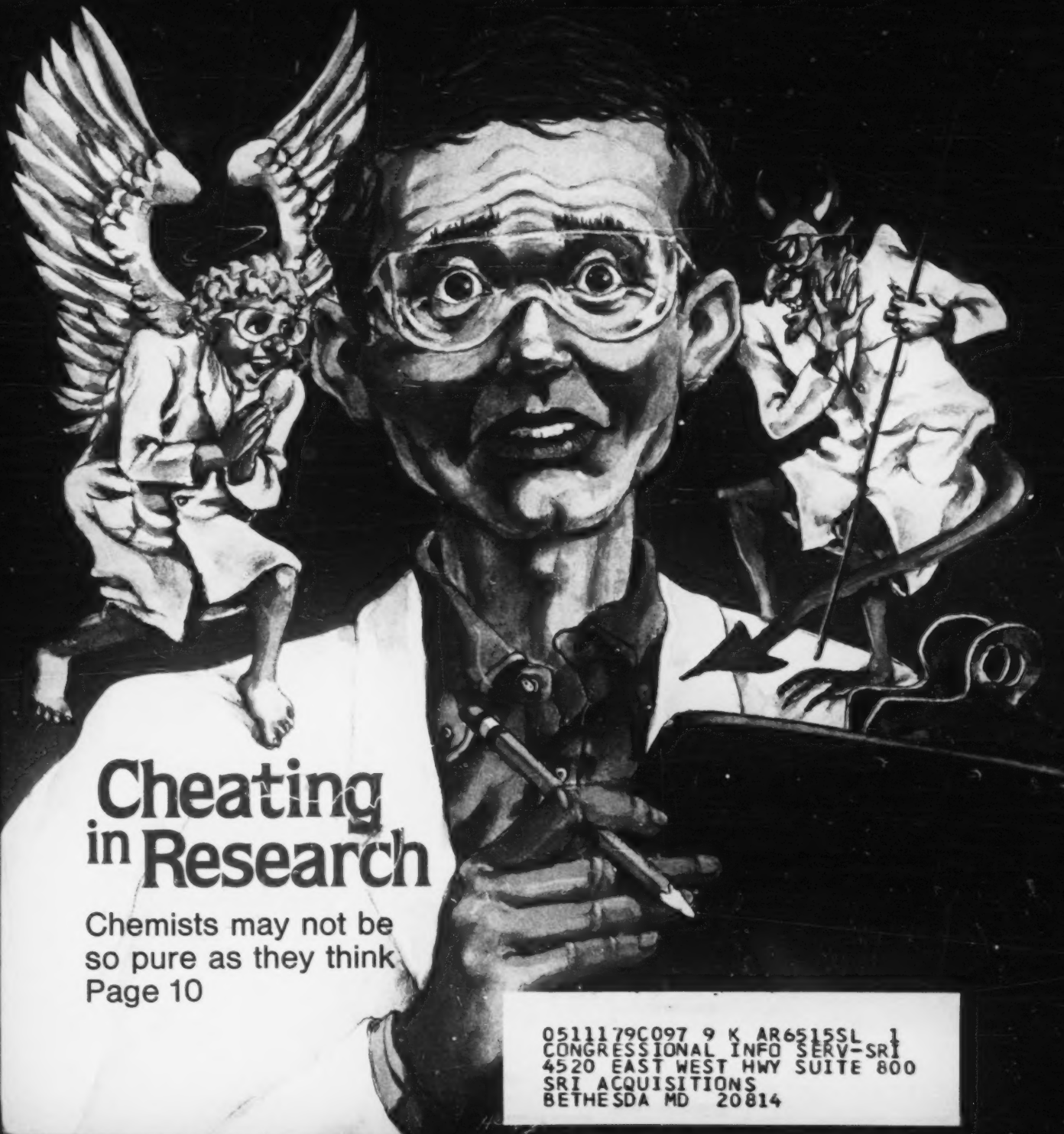
Top 50 chemical products
Page 20

APRIL 13, 1987

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CHEMICAL & ENGINEERING

NEWS



Cheating in Research

Chemists may not be
so pure as they think
Page 10

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News of the Week

■ Superconductivity tutorial at ACS meeting in Denver focuses on the role of chemists in the fast-moving field. **Page 4**

■ ACS Council, meeting in Denver, raises membership dues \$3.00, nominates two candidates for 1988 president-elect among other council business. **Page 5**

■ A drug search was conducted at Du Pont's Towanda, Pa., photographic products plant following discovery of drugs at work site. **Page 6**

■ Association of American Universities members to take a vote on antilobbying resolution. **Page 6**

■ Interleukin-2, used in cancer therapy, can activate the patient's immune system to destroy cancer cells, studies data indicate. **Page 7**

■ President Reagan agrees to consider acid rain accord at U.S.-Canada summit meeting. **Page 8**

■ U.K. chemicals capital spending to rise 3% in 1987, according to U.K. trade group survey. **Page 8**

Letters	2
Editor's Page	3
Concentrates	
Business	18
Government	27
Science	30
The Departments	
Meetings	36
Newsprints	52

Business

Production of chemicals in C&EN's Top 50 group stabilized in 1986, partly as a result of improved housing and automotive markets. **Page 20**

Output of polymers—plastics, synthetic fibers, and synthetic rubber—climbed again in 1986, reaching a record 52.2 billion lb. **Page 23**

Growing foreign debts of developing countries are adversely affecting U.S. chemical trade. **Page 25**

Monsanto begins semicommercial production of new phosphate fiber, a substitute for short fiber asbestos. **Page 26**

Government

Lobbying methods used by many universities to obtain federal funding for laboratory construction continue to stir controversy. **Page 28**

Chemical plant pilot inspection program conducted by OSHA is given mixed review by that agency. **Page 29**

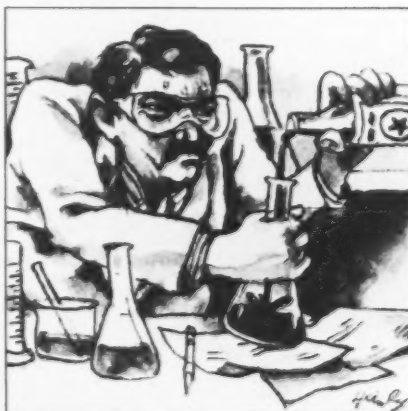
Science

IUPAC will label periodic table with Arabic numbers 1-18 in its next guidebook, scheduled for early 1988 publication. **Page 31**

U.K. introduces on-line microorganism database that will offer access to information on more than 30,000 microbial strains. **Page 33**

Books

"False Prophets: Fraud and Error in Science and Medicine" offers a lively account of cases of misconduct but few remedies. **Page 34**



News Focus

Chemists view fraud in chemical research as a rare occurrence, much less common than in other disciplines; however, misconduct may be more prevalent than they think. **Page 10**

Top 50 Chemicals Production Steadied in 1986

Output slipped slightly as organic chemicals rebounded to increase 9.2%; inorganic chemicals, however, continued their poor showing

Marc S. Reisch, C&EN New York

An improved housing market and a good year for auto production helped stabilize total U.S. chemicals output in 1986. Production was down a marginal 0.6% in 1986 compared with last year as indicated by C&EN's Top 50 chemicals group. This marked an improvement over

1985 when total U.S. production dropped 2% compared with the previous year.

The partial recovery due to improvements in housing and auto markets was dampened by the continuing slump in the U.S. farm economy. Also having a negative impact were imports of chemicals, which remained at historic high levels throughout 1986. However, U.S. exports of chemicals increased in 1986 with some help from a decline in the value of the U.S. dollar, which made chemicals cheaper for some foreign buyers.

Rebounding from 1985's poor showing, the organic chemicals component of the Top 50 showed the

greatest improvement. Production of those substances increased 9.2% compared with 1985. That was a decided improvement over 1985's production decrease of 1.9% compared with the previous year.

However, like the year before, 1986 was a poor one for inorganic chemicals nearly across the board. Output of the major fertilizer chemicals, including phosphoric acid, urea, and potash, continued to decline substantially. Other big-volume inorganics, such as nitric acid and ammonium nitrate, also showed large decreases. As a result, inorganic chemicals production declined 5.1% in 1986 compared with the previous year. Over the past five years,

About the Top 50 list of chemical products

Government data, trade association figures, and industry estimates all go into preparing C&EN's annual list of the Top 50 chemical products, ranked by production volume. The federal government is relied upon most heavily, but when government figures are not available other sources, primarily trade associations, are used. Industry sources and C&EN estimates are used only when other data are lacking.

Government data are not always accurate—they are only as good as the information that individual companies report. But they are an objective measure of production extending back many years. Therefore, relatively accurate indications of growth can be made on a consistent basis.

At this time of year, C&EN has access only to preliminary reports of production for 1986. When the government and trade associations issue their final reports, the outcome can be changed, sometimes dramatically. As a result, the production figures for ear-

lier years that appear in the table on page 21 are different in some cases from those published in last year's Top 50 report. The final reports also can affect the rankings of chemicals. The 1985 rankings of 33 chemicals listed in the table, for example, are different from those in the similar table published by C&EN a year ago (C&EN, April 21, 1986, page 12).

The list itself covers production figures for the U.S. and includes chemicals produced for export. Candidates for the list include all basic, intermediate, and chemically homogeneous finished products. These range from chemical building blocks like ethylene and propylene to downstream products like vinyl acetate and ethylene glycol.

The roster also includes basic inorganic chemicals, but does not include what C&EN considers to be minerals, such as salt, gypsum, and sulfur. Lime is included because it is processed and has many chemical and industrial

applications. Refractory (dead-burned) dolomite is excluded in the calculation of lime production.

In the organics list, such petrochemical feedstocks as ethane, butane, and propane are excluded arbitrarily because they are considered to be products of oil companies and because they have many nonchemical uses.

There are other gray areas besides lime and petrochemical feedstocks. For example, the basic aromatics—benzene, toluene, and xylene—are included. Admittedly, this makes the list less pure chemically.

Production figures are published by the government and trade associations in a variety of units—millions of pounds, thousands of tons, billions of cubic feet, millions of gallons, metric tons. To provide an accurate ranking and to make comparison of production volumes easier, C&EN not only gives production in common units but converts production to billions of pounds as well.

Top 50 chemicals production declined less than 1% last year

Rank			Billions of lb		Common units ^a		Average annual growth			
1986	1985 ^a		1986	1985	1986	1985	1985-86	1984-85	1981-86	1978-86
1	1	Sulfuric acid	73.64	79.30	36,822 tt	39,651 tt	-7.1%	-5.1%	-2.0%	0.5%
2	2	Nitrogen	48.62	47.46	671 bcf	655 bcf	2.4	-0.9	6.5	8.8
3	4	Oxygen	33.03	32.53	399 bcf	393 bcf	1.5	2.1	-1.5	0.4
4	6	Ethylene	32.81	29.85	32,811 mp	29,847 mp	9.9	-4.9	2.2	3.9
5	5	Lime ^c	30.34	31.60	15,172 tt	15,800 tt	-4.0	-1.2	-4.3	-2.3
6	3	Ammonia	28.01	34.64	14,005 tt	17,319 tt	-19.1	3.8	-6.0	-1.8
7	7	Sodium hydroxide	22.01	21.79	11,007 tt	10,893 tt	1.0	-0.2	1.1	0.5
8	9	Chlorine	20.98	20.79	10,489 tt	10,395 tt	0.9	-2.8	-0.5	0.1
9	8	Phosphoric acid	18.41	21.04	9,206 tt	10,518 tt	-12.5	-7.5	-1.6	1.5
10	11	Propylene	17.34	14.89	17,343 mp	14,887 mp	16.5	-4.3	5.2	5.6
11	10	Sodium carbonate ^d	17.20	17.19	8,600 tt	8,597 tt	0.0	1.0	0.8	5.1
12	15	Ethylene dichloride	14.53	12.10	14,529 mp	12,101 mp	20.1	13.0	7.8	6.1
13	12	Nitric acid	13.12	14.73	6,562 tt	7,364 tt	-10.9	-4.7	-6.3	-1.7
14	14	Urea ^e	12.06	13.36	6,029 tt	6,678 tt	-9.7	-10.2	-5.6	4.4
15	13	Ammonium nitrate ^f	11.11	13.55	5,556 tt	6,776 tt	-18.0	-5.2	-8.9	-2.5
16	17	Benzene	10.23	9.39	1,389 mg	1,275 mg	8.9	-3.3	1.2	-0.3
17	20	Ethylbenzene	8.92	7.39	8,915 mp	7,386 mp	20.7	-2.3	2.7	4.4
18	18	Carbon dioxide ^g	8.50	9.25	4,252 tt	4,623 tt	-8.0	1.3	2.3	8.0
19	16	Vinyl chloride	8.42	9.46	8,415 mp	9,463 mp	-11.1	55.5	4.1	4.0
20	19	Styrene	7.84	7.62	7,838 mp	7,622 mp	2.8	-1.1	3.3	2.2
21	21	Terephthalic acid ^h	7.68	6.49	7,684 mp	6,490 mp	18.4	9.8	4.3	0.6
22	27	Methanol	7.33	5.00	7,327 mp	5,003 mp	46.5	-38.9	-3.1	1.6
23	22	Hydrochloric acid	5.97	5.61	2,983 tt	2,807 tt	6.3	2.7	3.0	1.6
24	24	Ethylene oxide	5.94	5.43	5,943 mp	5,430 mp	9.4	-4.7	2.9	3.6
25	22	Formaldehyde ⁱ	5.89	5.61	5,885 mp	5,606 mp	5.0	-3.6	0.6	0.8
26	26	Toluene ^j	5.82	5.07	802 mg	699 mg	14.7	-4.0	-1.2	-2.2
27	25	Xylene	5.55	5.31	771 mg	738 mg	4.5	-13.6	-2.6	0.7
28	30	Ethylene glycol	4.76	4.18	4,759 mp	4,178 mp	13.9	-13.4	2.8	3.6
29	28	p-Xylene	4.67	4.78	4,669 mp	4,779 mp	-2.3	12.1	0.6	4.8
30	29	Ammonium sulfate	4.17	4.19	2,086 tt	2,093 tt	-0.3	1.3	-0.9	0.4
31	31	Cumene	3.70	3.35	3,695 mp	3,345 mp	10.5	-10.9	2.2	3.1
32	32	Acetic acid	2.93	2.90	2,931 mp	2,897 mp	1.2	10.6	-0.9	1.8
33	34	Phenol ^k	2.92	2.78	2,921 mp	2,777 mp	5.2	-3.9	2.5	3.3
34	39	Butadiene ^l	2.59	2.34	2,593 mp	2,340 mp	10.8	-4.6	-2.8	-3.0
34	35	Carbon black	2.59	2.57	2,585 mp	2,571 mp	0.5	-11.1	-1.1	-1.6
36	33	Potash ^m	2.58	2.84	1,169 tmt	1,288 tmt	-9.2	-17.6	-11.5	-6.0
37	36	Aluminum sulfate	2.52	2.54	1,258 tt	1,268 tt	-0.8	12.3	-0.6	0.5
38	37	Propylene oxide	2.48	2.40	2,480 mp	2,400 mp	3.3	34.9	6.1	3.1
39	38	Acrylonitrile	2.31	2.35	2,314 mp	2,346 mp	-1.4	5.7	3.0	4.3
40	40	Vinyl acetate	2.25	2.11	2,249 mp	2,112 mp	6.5	4.3	3.0	4.3
41	41	Methyl tert-butyl ether ⁿ	2.24	1.89	2,237 mp	1,891 mp	18.3	37.4	24.1	nm
42	44	Cyclohexane	2.07	1.66	2,071 mp	1,657 mp	25.0	-16.9	2.6	-0.5
43	42	Acetone	1.94	1.79	1,936 mp	1,788 mp	8.3	-4.0	-2.0	0.4
44	43	Titanium dioxide	1.83	1.72	917 tt	860 tt	6.6	3.0	3.8	2.5
45	48	Sodium silicate	1.57	1.44	786 tt	721 tt	9.0	-3.9	0.4	0.5
46	46	Calcium chloride ^o	1.56	1.88	780 tt	940 tt	-17.0	-10.4	-3.2	-4.2
47	45	Sodium sulfate ^p	1.55	1.65	775 tt	827 tt	-6.3	-5.2	-6.9	-4.5
48	47	Adipic acid	1.52	1.45	1,522 mp	1,453 mp	4.7	4.5	2.0	0.0
49	50	Isopropyl alcohol	1.28	1.24	1,275 mp	1,235 mp	3.2	-11.4	-5.2	-4.1
50	49	Sodium tripolyphosphate	1.27	1.25	634 tt	625 tt	1.4	-7.4	-1.8	-1.3
TOTAL ORGANICS			188.00	172.16			9.2%	-1.9%	1.8%	2.9%
TOTAL INORGANICS			350.60	369.56			-5.1%	-2.0%	-1.5%	0.8%
GRAND TOTAL			538.60	541.72			-0.6%	-2.0%	-0.5%	1.5%

^a Revised. ^b tt = thousands of tons, bcf = billions of cubic feet, mp = millions of pounds, mg = millions of gallons, tmt = thousands of metric tons. ^c Except refractory dolomite. ^d Natural and synthetic. ^e 100% basis. ^f Original solution. ^g Liquid and solid only. ^h Includes both acid and ester without double counting. ⁱ 37% by weight. ^j All grades. ^k Synthetic only. ^l Rubber grade. ^m K₂O basis. ⁿ Production data for earlier years unavailable. ^o Solid and liquid. ^p High and low purity. nm = not meaningful.

inorganics production has fallen at an average annual rate of 1.5%.

Half of the Top 50 chemicals registered an increase in production for 1986. By contrast, only 18 showed increased production in 1985. Total production was down 6.3% to 539 billion lb compared with the industry's historical high of 575 billion lb reached in 1979. The 1986 production level is 16.2% higher than the decade-low production level of 464 billion lb registered in 1982.

For the entire Top 50 group, composite output declined at a compound annual rate of 0.5% between 1981 and 1986. However, indicative of long-term growth, Top 50 production grew at an average annual rate of 1.5%.

The greatest individual growth in terms of production last year came mostly on the organics side. Methanol registered the largest production increase in 1986, up 46.5% to 7.33 billion lb. The gain pushed the chemical up to 22nd place on the Top 50 list from 27th place in 1985. The increase is all the more remarkable inasmuch as methanol showed the single largest output decline of any chemical on the Top 50 list in 1985, when production was down 38.9% compared with the previous year.

Next in terms of percentage gains among the organics in 1986 was cyclohexane, with output up 25% to 2.07 billion lb; ethylbenzene, up 20.7% to 8.92 billion lb following a

decline of 2.3% in 1985; and ethylene dichloride, up 20.1% to 14.53 billion lb.

On the negative side, the biggest decrease on the organics side in 1986 came from vinyl chloride, whose production fell 11.1% compared with the previous year, and urea, down 9.7%.

Although the inorganics component in 1986 showed the greatest declines from production levels in the year-earlier period, some chemicals did register relatively strong increases. Sodium silicate production grew 9% in 1986 to 1.57 billion lb compared with the previous year. More modest rates of increase were recorded by titanium dioxide, up 6.6% in 1986 compared with the year earlier to 1.83 billion lb; and hydrochloric acid, up 6.3% to 5.97 billion lb.

Slow growth or no growth, however, seemed to be more often the rule among the inorganic chemicals on the Top 50. Ammonia registered the largest decline in 1986, with production down 19.1% to 28.01 billion lb and dropping it to sixth place in the rankings of the Top 50 from third place in 1985. Also showing a considerable production decline was ammonium nitrate, down 18% from the previous year to 11.11 billion lb; followed by phosphoric acid, down 12.5% to 18.41 billion lb; and potash, down 9.2% to 2.58 billion lb.

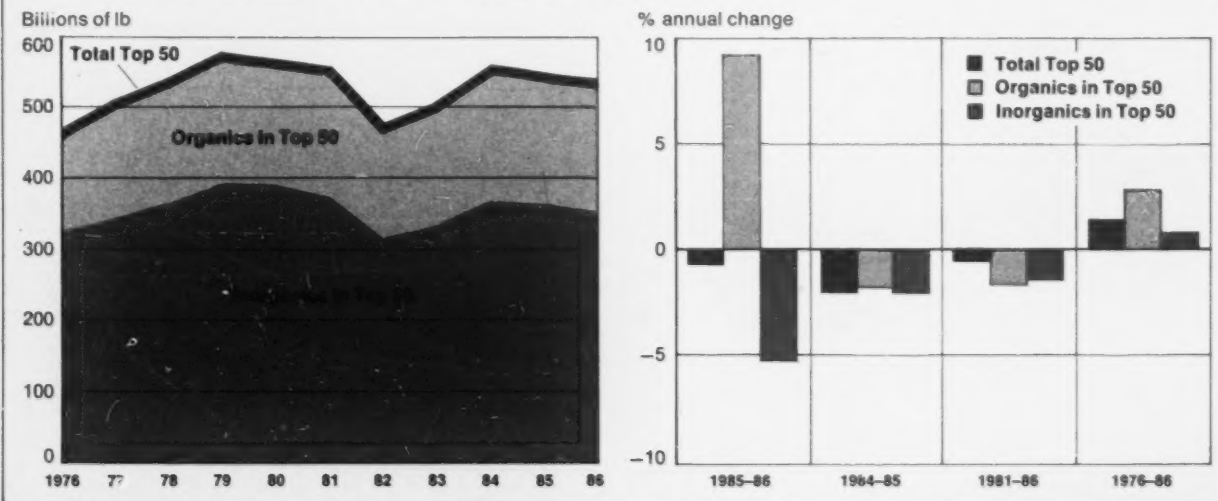
Revised figures for propylene ox-

ide for 1985 and 1986 as a result of more reliable information from industry sources have required drastic changes in this chemical's production. As a result, the average annual growth for the chemical between 1984 and 1985 at 34.9% in this year's C&EN listing is probably overstated. C&EN believes that the 3.3% growth reported for propylene oxide between 1985 and 1986 is a reliable indicator of the trend in this chemical's production.

Over the past five years, 27 of the Top 50 chemicals have registered increases in their growth rates. Leading in individual growth rates over the five-year span was methyl *tert*-butyl ether, whose production grew at an annual compound rate of 24.1%. Following this chemical in growth rate were ethylene dichloride, up 7.8% annually for the five-year period; nitrogen, up an average 6.5% a year; propylene oxide, up an average 6.1% a year; terephthalic acid, up an average 4.3% a year; and vinyl chloride, up an average 4.1% a year.

Leading the products with the largest individual decreases in production over the five-year period was potash, whose output fell at a compound annual rate of 11.5%. Other chemicals registering hefty decreases over the five-year period were ammonium nitrate, down 8.9% a year on average; sodium sulfate, down 6.9% a year on average; urea, down 5.6% year on average; and

Basic chemicals production continues to decline



isopropyl alcohol, down 5.2% a year on average.

Over the past 10 years, 34 of the Top 50 chemicals have recorded production increases. The best long-term performer has been nitrogen, whose output has grown at an annual compound rate of 8.8% during this period. Production of carbon dioxide also grew at a remarkable rate of 8%. Other chemicals with sizable annual compound growth rates were ethylene dichloride, up 6.1% between 1976 and 1986, and sodium carbonate, up 5.1%.

Potash has registered the greatest average annual rate of decline over

the past 10 years. Its output has fallen at a compound rate of 6%. Other products with shrinking output were sodium sulfate, down 4.5% a year on average; isopropyl alcohol, down 4.1% a year on average; calcium chloride, down 4.2% a year on average; and butadiene, down 3% a year on average.

The group comprising the 10 largest chemical commodities in terms of production was nearly the same. The one exception was sodium carbonate, which had ranked 10th on the 1985 list. It moved down a notch to become the 11th-ranked chemical on the 1986 list, switching plac-

es with propylene, the 11th-ranked chemical product in 1985.

There was a good deal of rank shifting through the rest of the list. In all, 33 of the chemicals on the list either moved up or down in the rankings.

Besides the rise already noted for propylene and the fall for sodium carbonate, other significant changes in rank included ethylene dichloride, which, with its 20.1% increase in production in 1986 compared with the year earlier, jumped to 12th place from 15th in 1985; and ethylbenzene, which jumped to 17th place from 20th place in 1985. □

Polymer output records fourth consecutive annual rise

Overall production of plastics, synthetic fibers, and synthetic rubber polymers reached a record high of 52.2 billion lb in 1986. The growth marked the fourth consecutive annual increase for the product group, lifting the output total 5.9% above the 1985 record and exceeding 50 billion lb for the first time.

Synthetic rubber displayed a spectacular recovery in 1986 as total output increased 8.1% after registering a significant decrease of 14.7% in 1985 from the year-earlier level. Production of styrene-butadiene registered a 7.8% annual growth rate last year following an enormous 23.3% drop in 1985 compared with the

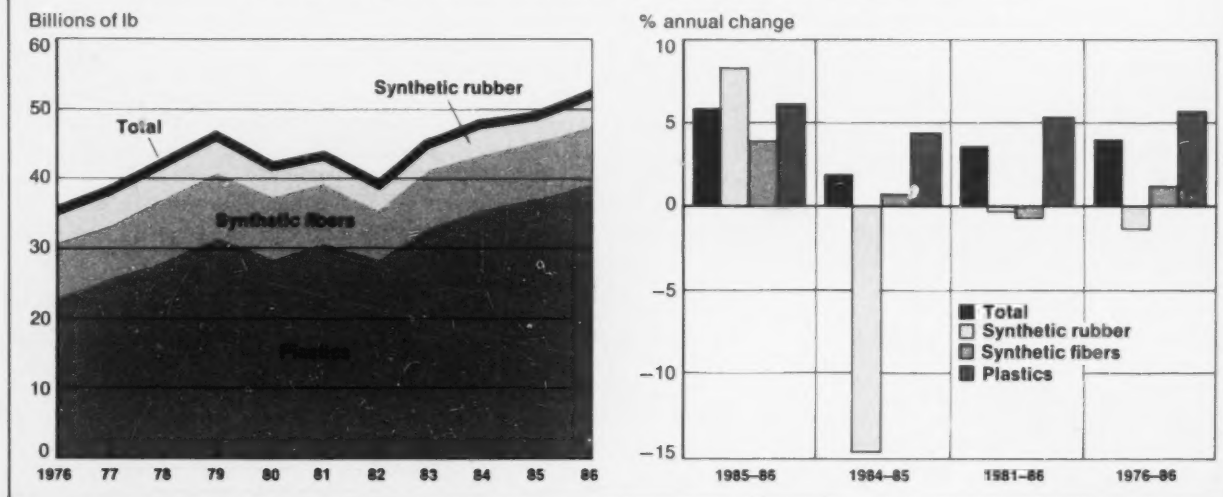
year earlier. Other synthetic rubber products showing significant production increases were nitrile, up 9.4% in 1986 after declining 20.9% in 1985 compared with the previous year; and ethylene-propylene, which resumed its upward growth at a healthy 7% in 1986 after registering no growth in the previous year. Also recording a strong growth of 15.2% last year were the synthetic rubber products reported as a group by the Rubber Manufacturers Association: neoprene; butyl; polyisoprene; chlorosulfonated polyethylene; polyisobutylene; and acrylo, fluoro, polysulfide, and silicone elastomers.

Only polybutadiene failed to reestablish a growth pattern in 1986, with production down 10 million lb from the year-earlier level. Polybutadiene registered a 1.5% decline from 1985, and an 8.1% decline compared with 1984.

However, the long-term picture for the synthetic rubbers group is not nearly so rosy as its 1986 production numbers alone might indicate. Over the past five years, this polymer segment's output has declined at an average annual rate of 0.3%, and 1.5% over the past 10 years.

Plastics account for more than two thirds of the polymer group production total. In 1986 this segment

Output increased for plastics, synthetic fibers, and synthetic rubber in 1986



Total polymers production exceeded 50 billion lb last year

	Billions of lb		Common units					Average annual growth			
	1986	1985	1986	1985	1984	1981	1976	1985-86	1984-85	1981-86	1976-86
PLASTICS (millions of lb)											
Thermosetting resins	5.83	5.63	5,834	5,631	5,549	5,010	3,633	3.6%	1.5%	3.1%	4.9%
Phenol, other tar acid resins	2.72	2.62	2,721	2,621	2,502	2,333	1,340	3.8	4.8	3.1	7.3
Urea resins	1.27	1.21	1,271	1,210	1,199	1,165	821	5.0	0.9	1.8	4.5
Polyesters (unsaturated)	1.27	1.22	1,271	1,223	1,232	997	1,042	3.9	-0.7	5.0	2.0
Epoxies (unmodified)	0.40	0.39	398	385	406	336	244	3.4	-5.2	3.4	5.0
Melamine resins	0.17	0.19	173	192	210	179	186	-9.9	-8.6	-0.7	-0.7
Thermoplastic resins	33.57	31.53	33,569	31,525	30,036	25,671	19,481	6.5%	5.0%	5.5%	5.6%
Low-density polyethylene	8.89	8.89	8,888	8,889	8,413	7,693	5,813	0.0	5.7	2.9	4.3
PVC and copolymers	7.26	6.77	7,256	6,772	6,760	5,707	4,716	7.1	0.2	4.9	4.4
High-density polyethylene	7.17	6.67	7,171	6,671	6,085	4,695	3,125	7.5	9.6	8.8	8.7
Polystyrene ^a	4.44	4.05	4,442	4,054	3,838	3,621	3,195	9.6	5.6	4.2	3.4
Polypropylene	5.81	5.14	5,812	5,139	4,940	3,955	2,632	13.1	4.0	8.0	8.2
TOTAL^b	39.40	37.16	39,403	37,156	35,585	30,681	23,114	6.0%	4.4%	5.1%	5.5%
SYNTHETIC FIBERS (millions of lb)											
Cellulosics	0.62	0.56	619	558	589	770	791	10.9%	-5.3%	-4.3%	-2.4%
Rayon	0.40	0.35	404	353	390	509	493	14.4	-9.5	-4.5	-2.0
Acetate ^c	0.22	0.21	215	205	199	261	298	4.9	3.0	-3.8	-3.2
Noncellulosics^d	7.82	7.56	7,815	7,564	7,473	7,982	6,615	3.3%	1.2%	-0.4%	1.7%
Polyester	3.30	3.34	3,304	3,341	3,392	4,173	3,341	-1.1	-1.5	-4.6	-0.1
Nylon ^e	2.52	2.34	2,515	2,343	2,412	2,333	2,076	7.3	-2.9	1.5	1.9
Olefin ^f	1.38	1.25	1,380	1,249	998	785	577	10.5	25.2	11.9	9.1
Acrylic ^g	0.62	0.63	616	631	671	691	621	-2.4	-6.0	-2.3	-0.1
TOTAL^b	8.43	8.12	8,434	8,122	8,062	8,752	7,406	3.8%	0.7%	-0.7%	1.3%
SYNTHETIC RUBBER (thousands of metric tons)											
Styrene-butadiene ^h	1.75	1.62	792	735	958	1,032	1,333	7.8	-23.3	-5.2	-5.1
Polybutadiene	0.72	0.73	325	330	359	342	352	-1.5	-8.1	-1.0	-0.8
Ethylene-propylene	0.51	0.47	230	215	215	178	130	7.0	0.0	5.3	5.9
Nitrile	0.13	0.12	58	53	67	66	73	9.4	-20.9	-2.6	-2.3
Other ^h	1.28	1.11	582	505	556	404	416	15.2	-9.2	7.6	3.4
TOTAL^b	4.38	4.05	1,987	1,838	2,155	2,022	2,304	8.1%	-14.7%	-0.3%	-1.5%

^a No longer includes acrylonitrile-butadiene-styrene or styrene-acrylonitrile resins; historical data are restated. ^b Totals are for those products listed. Totals may not add because of rounding. ^c Includes diacetate and triacetate yarn, but does not include cigarette tow. Beginning with 1985, includes rayon yarn. ^d Excludes aramid after 1982. ^e Includes olefin film, olefin fiber, spun-bonded polypropylene, and vinyon. ^f Includes modacrylic. ^g Excludes high-styrene latex. ^h Beginning with 1985, includes neoprene; historical data are restated. Also includes butyl; polyisoprene; chlorosulfonated polyethylene; polyisobutylene; and acrylo, fluoro, and silicone elastomers. Sources: Society of the Plastics Industry, Textile Economics Bureau, Rubber Manufacturers Association

continued its buoyant growth rate, with production up 6% from the year earlier. The strongest growth was registered by the thermoplastics side of the segment, with polypropylene recording the highest growth, 13.1%, followed by polystyrene, 9.6%, and high-density polyethylene, 7.5%. Overall thermoplastics production rose 6.5%.

By comparison, output of thermosetting resins grew 3.6% in 1986. Urea resins showed the best growth of all members of the group, with production up 5% compared with 1985. Polyester resins also sustained a good growth rate of 3.9% and phenol and other tar acid resins grew 3.8%. Only melamine resins, down 9.9%, continued their downward spiral after an earlier production decline in 1985.

For the 10-year period between 1976 and 1986, the plastics segment grew at an annual compound rate of 5.5%. For the five years between 1981 and 1986, plastics grew at an annual compound rate of 5.1%.

Though the slowest growing of the entire polymers products group, synthetic fibers nevertheless recorded a production increase of 3.8% in 1986 over the year-earlier level. Despite continued pressure from imported textiles, both cellulosic and noncellulosic fibers registered gains.

Output of cellulosic fibers, the smallest segment of the fibers group, showed the strongest recovery, rising 10.9% in 1986. Rayon and acetate were in greater demand for fashion apparel in the past year, helping the recovery.

The noncellulosics group, which accounted for more than 90% of fiber production last year, recorded a 3.3% increase in output last year. Olefins continued to lead the way in year-to-year production increases, up 10.5% in 1986. Nylon also showed substantial growth in 1986, up 7.3% owing in part to heavy demand for carpet fibers.

Other members of the noncellulosics group did not fare so well. Heavy demand for acrylic sweater yarns still did not translate into higher acrylic production in 1986. Acrylic fiber output fell 2.4% in 1986. And polyester production also declined in 1986. Production of this fiber slipped 1.1% as polyester makers shut down textile filament production because of lagging demand. □

U.S. chemical trade hurt by developing country debt

The foreign debts of many developing countries seem to be a problem that just won't go away. The total foreign debt of just the five largest developing country debtors (Brazil, Mexico, Argentina, Venezuela, and the Philippines) now tops \$330 billion. Rather than declining, this debt burden is increasing.

In the developing countries themselves, these staggering debts are raising havoc with domestic economies and their social, labor, and political structure. But the impact also is being felt in the U.S., and that impact extends far beyond the bottom lines of the banks that lent these countries the money in the first place.

As these countries adopt economic policies to cope with their debt, the trade, even the output, of many U.S. manufacturing industries has suffered. Among the hardest hit is the chemicals and allied products industry. The reason: To build foreign exchange for repaying their debts, these countries typically curb their imports and do everything they can to push exports. As a result, U.S. industries that rely on developing countries as major markets for their products feel the pinch.

The U.S. chemical industry is one of those industries. In 1980, more than \$9 billion, or about 44% of U.S. chemical exports, went to developing countries. That is the year in which the U.S. chemical trade surplus (excess of exports over imports) hit a record \$12.1 billion.

By 1985, the U.S. chemical trade surplus had slipped to \$7.2 billion. Not surprisingly, exports to developing countries had shrunk to 36% of the total (\$7.8 billion). Meanwhile, U.S. imports from these developing countries (the so-called Third World) grew from \$942 million to \$2.3 billion.

Last year, the U.S. chemical trade picture with the Third World improved somewhat. Chemical exports bounced back to \$8.5 billion, but imports remained essentially flat at \$2.4 billion. However, those exports still are only 37% of the U.S. chemical industry's total, far below the 1980 share.

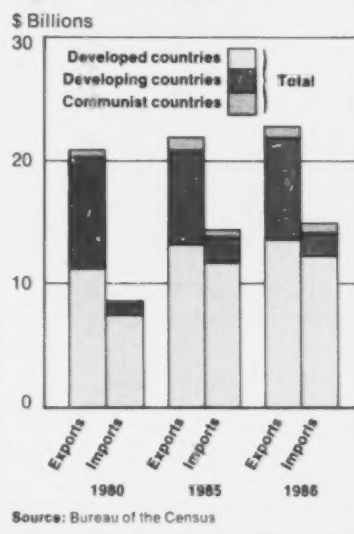
A recent International Trade Commission (ITC) study indicates that, in 1985, the debt-related austerity measures adopted by the five largest Third World debtors hurt the trade balance in 40 of 61 nonservice U.S. industries. Hardest hit was the automotive and auto equipment industry. Right behind it was the chemical industry.

ITC estimates that, between 1980 and 1985, producers of "chemicals and selected products" lost almost \$1.3 billion in their trade balance with these five countries. Throw in other products normally associated with the chemical industry, and the drop in the chemical trade surplus adds up to more than \$1.6 billion. These products include plastics and synthetic materials, drugs, cleansers, toiletries, and paints and allied products.

The combination of lost exports and additional imports from these debtor countries has crimped U.S. chemical industry output. But the impact goes beyond the year-to-year drop in exports and the gain in imports. To ITC's way of thinking, a better measure is to compare actual 1985 trade data with what the situation might have been if both chemical exports and imports had retained a constant market share.

For its analysis, ITC selected the average market share in the 1979-81 period, which it refers to as the "predebt crisis" period. Thus, ITC assumes that, without a debt prob-

Developing nations' share of U.S. chemical exports down from 1980



lem, each debtor developing nation's share of U.S. exports and imports would have been the same as it was before the debt crisis.

In its analysis of the five largest debtor countries, for instance, ITC estimates that net trade (exports less imports) for the chemicals and selected products segment of the industry would have been \$1.6 billion in 1985 if exports and imports had retained their 1979-81 average market share. That's more than double 1985's actual net trade of \$778 million.

U.S. chemical trade drops with debtor developing nations

\$ Millions	Chemicals & selected products	Plastics & synthetic materials	Drugs, cleaning & toilet preparations	Paints & allied products	All products
1978	\$ 1170	\$ 349	\$ 175	\$13	\$ -348
1979	1695	584	198	11	-119
1980	2050	723	235	15	3,220
1981	1681	687	251	19	2,242
1982	1232	571	226	24	-6,039
1983	753	454	173	20	-14,718
1984	987	388	201	24	-17,349
1985	778	407	165	25	-15,103
Net change 1980-85*	\$-1272	\$-316	\$-70	\$10	\$-18,233

Note: U.S. net chemical trade (exports minus imports) with five debtor developing countries—Mexico, Brazil, Argentina, Venezuela, and the Philippines. * 1980 was chosen because it was the year in which the U.S. chemical trade surplus was the largest. Source: International Trade Commission

U.S. chemical output crimped by trade with debtor nations

\$ Millions	Chemicals & selected products	Plastics & synthetic materials	Drugs, cleaning & toilet preparations	Paints & allied products
NET TRADE^a				
Actual net trade, 1985	\$778	\$407	\$165	\$25
Net trade at constant market share ^b	\$1661	\$614	\$271	\$16
Difference	\$-883	\$-207	\$-106	\$9
Estimated change in industry output	\$-1596	\$-336	\$-128	\$-32
Estimated change as % of output	-1.97%	-0.91%	-0.23%	-0.34%
EXPORTS				
Ratio, 1985 exports to 1978-81 average	0.696	0.803	0.659	1.572
Actual exports, 1985	\$1538	\$512	\$221	\$25
Exports at constant market share ^b	\$2212	\$637	\$335	\$16
Difference	\$-673	\$-125	\$-114	\$9
Estimated change in industry output	\$-1046	\$-202	\$-134	\$-12
Estimated change as % of output	-1.29%	-0.55%	-0.24%	-0.12%
IMPORTS				
Ratio, 1985 imports to 1978-81 average	1.380	4.593	0.887	0.940
Actual imports, 1985	\$761	\$105	\$56	neg
Imports at constant market share ^b	\$551	\$23	\$64	neg
Difference	\$210	\$82	\$-8	neg
Estimated change in industry output	\$551	\$133	\$-5	\$20
Estimated change as % of output	0.68%	0.36%	-0.01%	0.21%

Note: U.S. chemical trade with five debtor developing countries—Mexico, Brazil, Argentina, Venezuela, and the Philippines. ^a Exports minus imports. ^b What 1985 exports (or imports) would have been if they had retained their 1978-81 average market share. neg = negligible. Source: International Trade Commission

Based on such a comparison, ITC also estimates that the output of this segment of the industry was \$1.6 billion lower than it would have been without a developing country debt crisis. That's an almost 2% drop in output, based on changing trade fortunes with only five developing countries.

Adding in the other segments of the chemical industry, such as plastics, drugs, and paints, brings the total estimated output loss in 1985 to more than \$2 billion.

Between 1981 and 1985, while the debt burdens of many developing countries were growing to enormous proportions, the U.S. dollar was becoming stronger against most major currencies. Virtually all economists agree that the strengthening dollar was the leading cause of the poor U.S. export performance and the massive U.S. trade deficit.

In some cases, it is difficult to separate and identify the effects of country debt and the effects of the dollar on trade. Not so with the major debtors among the developing countries.

Just as it did against major trading currencies, the U.S. dollar also became stronger against the Mexican peso, the Brazilian cruzeiro (now the cruzado), and other currencies of debtor countries in the Third World. But the onus for the U.S. trade problems with these countries still rests squarely on the debt-related austerity policies initiated by these countries.

Stephen Cooney, director of international investment and finance at the National Association of Manufacturers, says there is a direct relationship between the rapid depreciation of many developing countries' currencies and the debt crisis. And, he adds, resolving these debt problems is crucial, not only to the economic health of these countries, but to improvement in U.S. export fortunes.

Despite the improvement in the U.S. chemical trade picture with Latin America last year, Cooney says that "we [the U.S.] are far from recovering our trade position in Latin America."

Earl Anderson, New York

Monsanto launches substitute for asbestos

Monsanto brought its first semi-commercial phosphate fiber plant on stream in St. Louis last month. With an annual capacity that Monsanto phosphate fiber program director Joseph J. Narciso sets at a few hundred tons, the plant takes the company a step toward recovering the investment it has made so far in its replacement for short fiber asbestos.

Monsanto's phosphate fiber is a patented synthetic, crystalline, polymeric fiber of calcium sodium metaphosphate. The fiber boasts very high temperature stability (to 470 °C) and also handles and processes very much like short asbestos fibers in gasket and friction materials, according to Narciso.

With this fiber development under way, Monsanto joins the host of manufacturers rushing in to provide adequate substitute materials in support of the Environmental Protection Agency's mandate to ban asbestos use where workable substitutes exist (C&EN, March 16, page 17).

The fiber's main selling point, says Narciso, is that it is not "bio-durable" and, unlike asbestos, isn't likely to pose significant health risks. Asbestos has been labeled a carcinogen because the tiny asbestos fibrils have a tendency to attach themselves to lung tissue.

Monsanto is near completion of a two-year inhalation study of its phosphate fiber in rats. Results so far substantiate the company's claim that the fiber is not bio-durable, Narciso says.

Development quantities of the fiber are now available at \$2.00 per lb. Price is expected eventually to be between \$1.00 and \$2.00 per lb depending on market end use, Narciso says, putting the final price just above the cost of glass fiber but below the cost of aramid fiber, the two fibers Monsanto considers its principal competitors.

Monsanto's phosphate fiber has potential for use in brake linings, gaskets, thermal-resistant papers, caulks, and putties.

Marc Reisch, New York

APRIL 20, 1987

CHEMICAL & ENGINEERING

NEWS

1986 ACS Annual Report Page 33
Scientific news from the
Denver ACS meeting

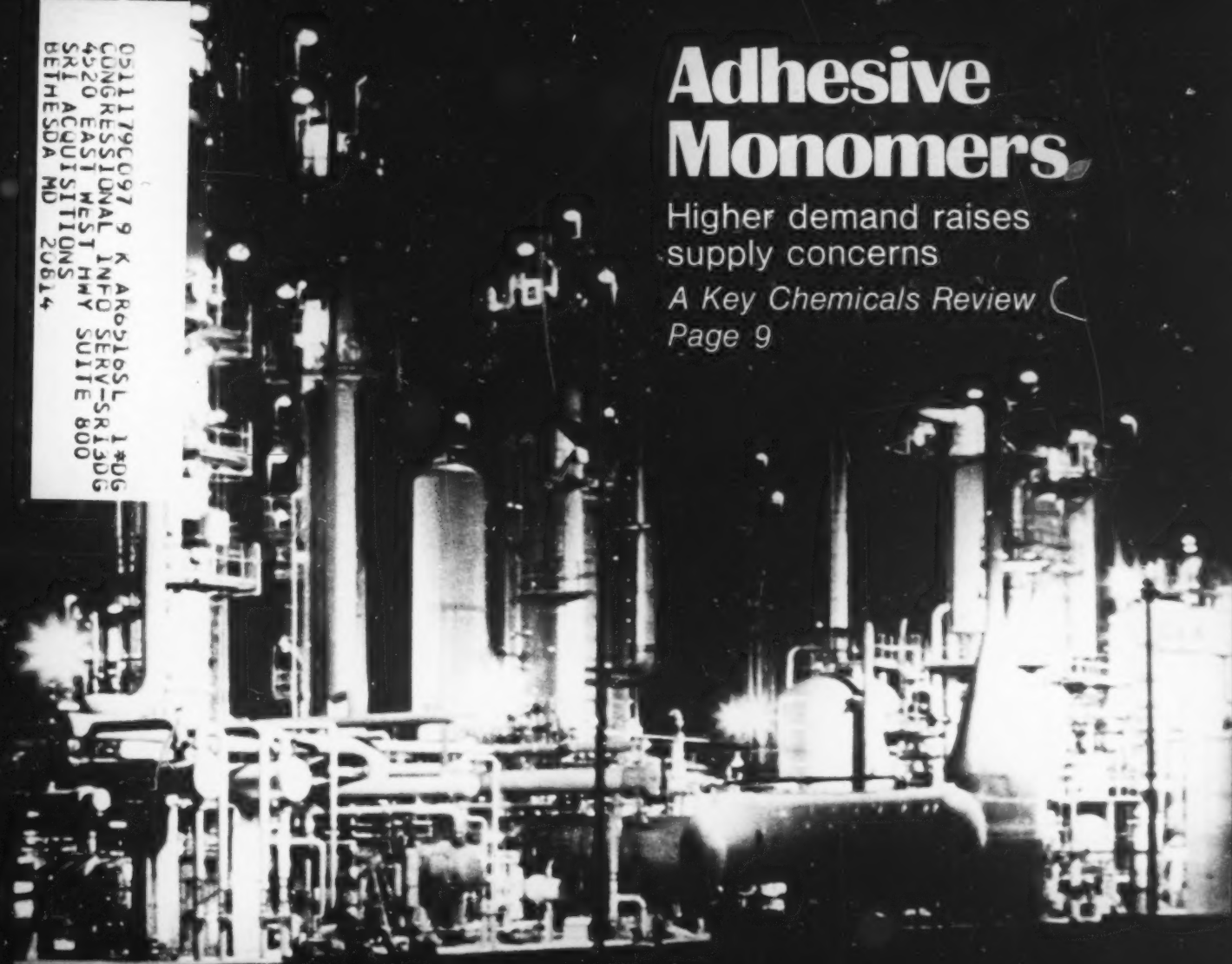
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Adhesive Monomers

Higher demand raises
supply concerns

A Key Chemicals Review
Page 9



News of the Week

■ Merrill Lynch agrees to acquire Borg-Warner in leveraged buyout. **Page 4**

■ Independent research at two labs yields information on structure of new AIDS virus and mode of action of AIDS virus on human cells. **Page 5**

■ Texaco continues daily operations after filing for bankruptcy under Chapter 11. **Page 6**

■ Complaints about preshipment inspection companies are aired at an International Trade Commission hearing. **Page 6**

Cover: Aristech's phenol unit at Haverhill, Ohio

Letters	2
Concentrates	
Business	7
Government	13
Science/Technology	22
The Departments	
Meeting Briefs	67
ACS Comment	69
People	72
Newsclips	84

Government

ACS Denver symposium examines tax reform, with its lower rates and more complex features. **Page 14**

Federal support for science is high, but scientists at AAAS symposium are concerned about how research funds will be divvied. **Page 16**

Science

From the Denver ACS meeting: drug testing in the workplace; removal of heteroatoms from coal liquids; radiocarbon dating of the Shroud of Turin; 3-D aromaticity of adamantane dication; enhanced resolution of NMR spectra through use of supercritical solvents. **Page 26**

ACS Annual Report

Adoption of revised mission statement, initiation of plans for National Chemistry Day, and expanded involvement in public affairs highlight ACS in 1986. **Page 33**

Education

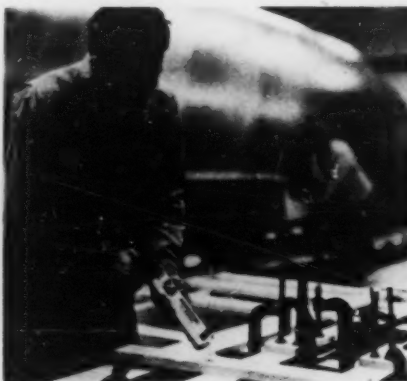
From the Denver ACS meeting: Chemistry textbook errors persist as a result of difficulty in tracking them, writers' ignorance. **Page 62**

Technology

From the Denver meeting: expanded use of robotics in industrial labs; concentration of kerogen from oil shale. **Page 63**

ACS News

Wide variety of activities at the society's national meeting in Denver captured on film by roving photographer. **Page 70**



Business

The increase in demand for major adhesive monomers formaldehyde, phenol, and vinyl acetate and high plant operating rates are raising the prospect of supply shortages. **Page 9**

Supply Problems Loom for Big-Volume Adhesive Monomers

Increasing demand for phenol, vinyl acetate, and formaldehyde, coupled with high plant operating rates, raises specter of shortages

Bruce F. Groek, C&EN Houston

Concern is growing over the possibility of shortages in the supply of major adhesive monomers. Capacity utilization of plants producing two of them—phenol and vinyl acetate—is now nearing the effective limit. Plants making the other intermediate, formaldehyde, still have a low utilization rate, but that situation could change quickly if demand continues to rise and plant shutdowns cut capacity drastically.

Additions to capacity to make these materials, other than minor debottlenecking, if initiated now, will not be available until near the end of the decade. There have been no recent announcements or rumors

of sizable additions, even as capacity utilization has risen. Producers have considered expansions unjustified in view of the low prices they have been receiving. Although prices have risen and are rising, they still are below levels allowing an adequate return on investment, especially in competition with depreciated plants.

Prices could continue to increase,

Key Chemicals

as supplies of these materials tighten. Fortunately, such increases could help the supply situation for phenol and vinyl acetate by curtailing exports. Price increases likely will dampen U.S. demand for these materials in end uses where their cost/performance qualities are only marginally better than for other materials. Prices of exports usually are below U.S. prices, and export prices could be kept down in the future

by competition from new plants being built outside the U.S. Such price incentives could shift supplies to the U.S. market.

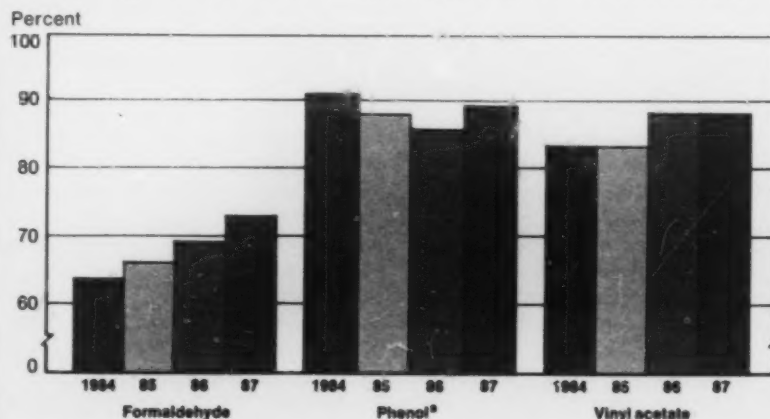
A decrease in exports of both phenol and vinyl acetate can provide a substitute for capacity expansions to meet U.S. demand for these monomers. Because more than a quarter of vinyl acetate production is exported, it has the largest cushion of material available to supply U.S. consumers. Exports of phenol, although increasing, are much smaller, but are equivalent to some two to three years of recent demand growth in the U.S. Very little formaldehyde is exported; most of it is handled as solutions and it is too costly to ship as solutions to export markets.

If prices and demand for the monomers in the U.S. keep rising, a shift from substantial exports to some imports eventually could occur, although that doesn't seem likely in this decade. World demand for these adhesive materials also continues to rise, and in many places faster than in the U.S. The increased demand is absorbing the new capacity being built in such areas as Japan, South Korea, and Taiwan.

Higher prices for the major adhesive materials will have little effect on U.S. demand. In most adhesive applications, no acceptable substitutes exist that provide the necessary properties. However, in other, smaller uses, some materials could replace the monomers. For example, demand for various textile sizes made using polyvinyl alcohol from vinyl acetate could decline significantly if imports of apparel continue to rise in spite of various efforts to curb those imports.

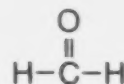
For details of the near-term outlook for these adhesive materials, please see the following pages.

Operating rates rise for most major adhesive monomers



^a Synthetic only. Source: C&EN estimates

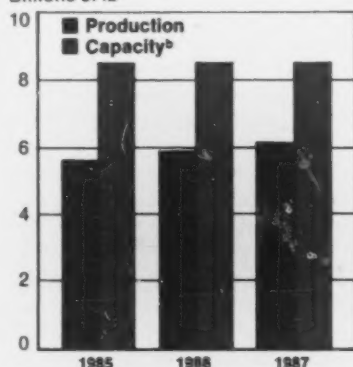
Formaldehyde



- **Output rising slowly**
- **Capacity on hold**
- **Prices firming**

PRODUCTION/CAPACITY

Billions of lb^a



^a As a 37% solution. ^b First quarter, some capacity may not be operable but not yet scrapped.

MAJOR PRODUCERS

Borden, Celanese, Du Pont, Georgia-Pacific, Monsanto

HOW MADE

Catalytic oxidation of methanol

MAJOR DERIVATIVES

Urea-formaldehyde resins 30%, phenol-formaldehyde resins 25%, acetylenic chemicals (mostly 1,3-butanediol) 5%, polyacetal resins 5%

MAJOR END USES

Adhesives 65%, plastics 15%

FOREIGN TRADE

Exports and imports small, each about 10 million lb per year

PRICE

AL 19 cents per lb, list, at merchant producer plants on Gulf Coast

Formaldehyde production will increase in 1987. However, growth will be slower than last year if housing demand holds at current levels. Capacity is more than adequate and will remain so, even though ownership of a few plants is changing and some units are being shut down. Because prices of methanol—the raw material for formaldehyde—have recovered, the relatively small merchant market is strengthening.

Housing generally accounts for about two thirds of U.S. formaldehyde consumption. If housing demand roughly equals last year's, then output of formaldehyde will expand more than 4%, or 300 million lb as 37% solution. (Other concentrations of solutions are available in the merchant market, including a solid form, but traditionally the industry reports production in terms of the 37% solution.) Housing plus additional demand for other uses could boost output to more than 6.2 billion lb as 37% solution. At that level, however, production still would match roughly that of 1978 and 1979 and would be below 1973's output of more than 6.4 billion lb.

If housing starts decline as much as the 10% forecast by less optimistic views of this market, formaldehyde output then will be flat or up less than 1% to amount to 5.9 billion to 6.0 billion lb. The preliminary estimate for 1986 production by the U.S. International Trade Commission is 5.89 billion lb, up from 5.61 billion lb in 1985 and largely because of strong housing demand.

U.S. nameplate capacity for formaldehyde is about 8.5 billion lb as 37% solution. Because demand for derivatives used as adhesives varies seasonally, not all of the units are operated at any one time. Some that make formaldehyde for captive use are located at or near consumption sites—such as plywood manufacturing plants—and have relatively small capacities. On the average, however, formaldehyde capacity will be operated at close to 72% of nameplate this year, slightly

higher than in the two preceding years. More smaller units are expected to be shut down because of current excess capacity.

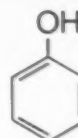
Excess capacity continues to keep pressure on the selling prices of merchant formaldehyde. About a quarter of all production enters the merchant market, either directly or as incremental output that remains after captive demands are met. Last year, selling prices fell to about 6 cents per lb, spurred in large part by declines in methanol prices that followed the decline in natural gas prices. Now that gas has become more expensive and a few methanol units have been shut down, methanol prices have increased to about 30 cents per gal, spurring increases in formaldehyde prices.

Demand for formaldehyde has little impact on prices because of overcapacity. The quantity of formaldehyde consumed in adhesives and other components used in construction is small if compared to quantities of other materials. As a result, new home prices have almost no effect on formaldehyde prices.

Well over half of formaldehyde consumption is accounted for by two kinds of resins: urea-formaldehyde and phenol-formaldehyde. The major use of these resins is adhesives for fiberboard, particleboard, and plywood. Growth in demand for formaldehyde in major uses is forecast to average about the same as growth in gross national product (GNP).

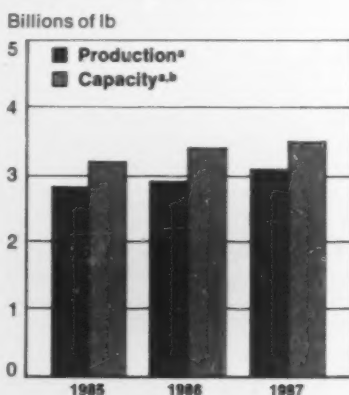
Other uses of formaldehyde are diverse. Many of its derivatives go to industries facing severe import competition, such as textiles. Growth forecasts in these areas are about the same as growth in GNP. Two derivatives, certain polyacetal resins and 1,4-butanediol, accounting for less than 20% of formaldehyde consumption, have growth rates above 5% annually. That is not large enough to cause the total consumption of formaldehyde to rise much above 2% annually in good years.

Phenol



- **Output to increase**
- **Capacity up**
- **Prices higher**

PRODUCTION/CAPACITY



^a Synthetic only. ^b First quarter.

MAJOR PRODUCERS

Allied-Signal, Aristech, Dow Chemical, General Electric, Georgia-Gulf, Shell Chemical

HOW MADE

Peroxidation of cumene (isopropyl benzene) and cleavage to phenol and coproduct acetone

MAJOR DERIVATIVES

Resins (mostly with formaldehyde as comonomer) 40%, bisphenol A 20%, caprolactam 15%

MAJOR END USES

Adhesives 40%, plastics 25%

FOREIGN TRADE

Exports nearing 200 million lb; imports small and holding at about 10 million lb

PRICE

38 to 40 cents per lb, list, after temporary voluntary allowances

The price of phenol will soar this month to 42 cents per lb, stimulated by rises in the cost of raw materials, mostly benzene. In addition, the price increases will be supported by limitations on available capacity to meet rising demand and by future growth in the various uses of phenol.

Output of phenol in 1987 likely will set a record of more than 3 billion lb. If demand for phenolic resins in housing construction continues at its 1986 pace, if exports increase, and if the demand for phenol to make other derivatives rises, then production will total between 3.05 billion and 3.10 billion lb. This would be about 150 million lb more than 1986 production of 2.92 billion lb, according to preliminary estimates of the U.S. International Trade Commission. Previous record production for synthetic phenol was 2.95 billion lb in 1979. Production last year was up more than 100 million lb from 2.78 billion lb in 1985.

Synthetic phenol capacity continues to increase, mainly through debottlenecking programs by nine producers. Several other companies are separating a small quantity of natural phenol—less than 50 million lb per year—from petroleum fractions and coal tar. At the beginning of 1987, synthetic phenol capacity was less than 3.5 billion lb, although some of that capacity may not have been utilized. Based on estimated total production for 1987 and operable capacity available for the year, the average operating rate will be about 90% of nameplate capacity.

The relatively high operating rate anticipated for phenol plants in 1987 is typical of rates in recent years. Even with the high operating rates, however, phenol prices have been under pressure.

As crude oil prices declined in 1986, the price of benzene, phenol's major raw material, also fell. Phenol prices slipped below 20 cents per lb, even though demand was strong owing to the need for resins, bisphenol A, and nylon 6. Following increasing crude

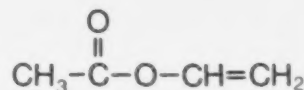
prices early this year, benzene prices increased sharply, with the spot price of benzene about doubling to nearly \$1.40 per gal. By March, prices of phenol precursor cumene had increased about 50%, but phenol increased only about 20 to 25%.

Most phenol producers are pushing for substantial price increases. For example, Dow Chemical has raised its contract list price for phenol to 42 cents per lb. Aristech and Shell also have posted similar hikes in list prices. Actual selling prices, now about 30 cents per lb, are expected to go up, but by less than the list price increases, unless benzene tabs continue to rise as a result of more demand for gasoline this summer or because of continued lackluster action in acetone prices.

It is uncertain how substantially increased prices will affect phenol demand and production. Many factors will impinge on production this year. For example, because of the low prices for phenol that producers received in 1986, inventories were drawn down to unusually low levels by year's end. Exports in 1986 increased from 141 million lb to an estimated 180 million lb and are expected to increase further this year. A relatively mild winter has allowed some construction (especially commercial) to move ahead faster than expected, increasing demand for adhesive resins for wood board products as well as for other fabricated phenolic resin products.

The market for other major-volume phenol derivatives, such as bisphenol A and caprolactam, also could be spurred by construction demand. Much of bisphenol A goes into epoxy and polycarbonate resins, whereas most phenol-based caprolactam goes to nylon 6, the bulk of which, in turn, becomes carpet fibers. These two uses now account for about one third of phenol consumption and are still growing faster than phenolic resins. They continue to be a strong driving force for increased phenol production.

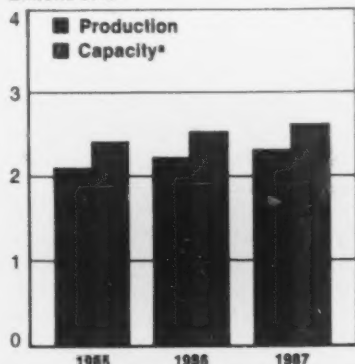
Vinyl Acetate



- **Production growing**
- **Capacity up modestly**
- **Prices rising**

PRODUCTION/CAPACITY

Billions of lb



* First quarter.

MAJOR PRODUCERS

Celanese, Du Pont, Union Carbide, USI Chemicals

HOW MADE

Vapor-phase reaction of ethylene, acetic acid, and oxygen

MAJOR DERIVATIVES

Polymers 55%, polyvinyl alcohol 20%, copolymers (mostly with butyraldehyde, ethylene, or vinyl chloride) 20%

MAJOR END USES

Adhesives 35%, paints 30%, paper and textile coatings 25%

FOREIGN TRADE

Exports holding at 600 million to 650 million lb; imports very small, less than 15 million lb

PRICE

About 27 cents per lb

Vinyl acetate needs a major new use to move it out of a slow growth pattern. But none have emerged. Consequently, output this year will increase only about 2%, the same annual rate as during the early 1980s. Some capacity expansion will result from debottlenecking programs. Prices have begun to rise this month.

Some of vinyl acetate's major uses are growing moderately and others are growing a little or not at all. And exports are declining. Some polymers—namely polyvinyl acetate and vinyl acetate-ethylene resins—continue to be the large growth products of vinyl acetate. However, use in these polymers is forecast to increase only 2 to 4% annually for the rest of this decade. Their growth will depend on their use in paints and adhesives. The polymers also find substantial use in products facing strong competition from other materials, tending to dampen their overall growth.

Exports of vinyl acetate for 1987 are forecast to be some 636 million lb, about equal to last year's. Exports in 1986 were up 60 million lb from 1985; they peaked in 1982 at almost 698 million lb.

If global demand for vinyl acetate slows and plant expansion outside the U.S. increases more than expected, this year's forecasts for exports could be too high. But exports likely will be at least 600 million lb. As capacity increases in Asian countries, exports could continue to decline slowly.

A decline in exports would not spur production, but would allow producers to meet, without the cost of major capacity expansions, the slowly growing demand in the U.S. Debottlenecking programs always will add a small amount to capacity, increasing it about the same as growth in production. Such minor capacity gains keep capacity utilization high. For example, production in 1986 increased to 2.25 billion lb, according to preliminary estimates of the U.S. International Trade Commission. Hence, with exports flat or

down slightly and with U.S. consumption rising 2%, 1987 output will be about 2.3 billion lb. If output totals 2.3 billion lb, and nameplate capacity for the year averages 2.6 billion lb, the operating rate will be more than 88%, down slightly from the 1986 rate. Production, however, could be limited by a shortage of acetic acid, which is reacted with ethylene and oxygen to make vinyl acetate.

A 2% growth in U.S. vinyl acetate demand, or about 50 million lb this year, will result largely from its use in paints and adhesives, which accounts for more than half of polyvinyl acetate demand (almost entirely as emulsions). That alone is more than one half of vinyl acetate production. Several years ago, interior latex paints led demand growth because they were replacing solvent-based paints. Interior latex paints have completed their takeover and now paint demand growth will depend on housing construction. Housing construction likely will be flat to slightly up in 1987, providing a modest growth for vinyl acetate. Polyvinyl acetate adhesives also go into construction uses as well as many packaging uses where growth now is forecast at about that of gross national product. Paper coating use, at about half of either paints or adhesives, is expected to improve because demand is high for quality printing.

As a vinyl acetate use, polyvinyl alcohol is less than a third of that for polyvinyl acetate. Its largest application is in textile sizes, but no growth is forecast because imports of apparel are increasing.

Among copolymers made with vinyl acetate, use of polyvinyl butyral may be somewhat larger than that of the copolymers made with ethylene. Polyvinyl butyral has one major use—the adhesive film that goes into safety glass for both automotive and architectural markets. No growth is expected in polyvinyl butyral this year because smaller cars are being built and fewer office buildings are being constructed.

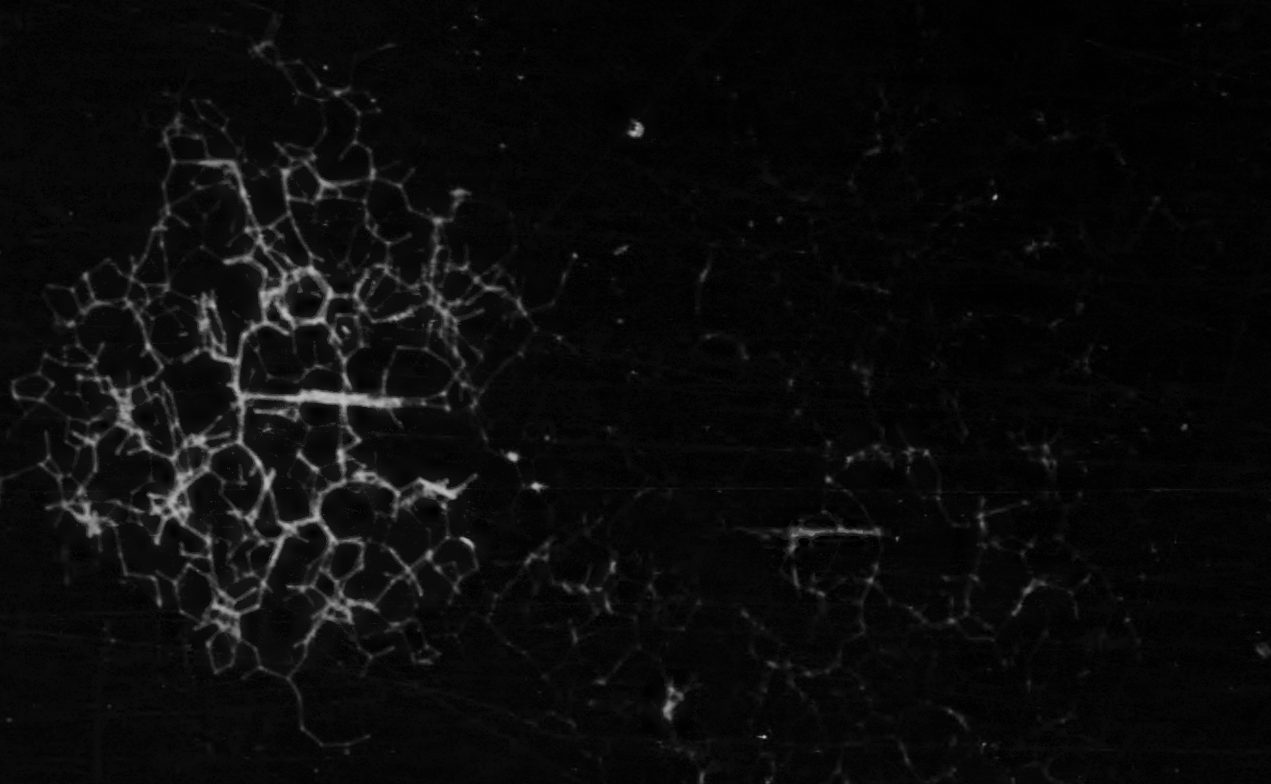
Top 100 chemical producers
Page 9

MAY 4, 1987

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CHEMICAL & ENGINEERING

NEWS



Biological Electron Transfer

Researchers explore factors
that govern rates Page 19

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News of the Week

■ UN report on ecological awareness calls for new era of economic growth, offers agenda for future based on concept of sustainability. **Page 4**

■ Although first field tests of genetically engineered bacteria to clear all state and federal hurdles have been conducted, they may not ease the way for future tests. **Page 5**

■ U.S. output of specialty chemicals packaged in aerosol containers rose 4.7% in 1986, the fourth straight year of real growth. **Page 5**

■ Investor Harold Simmons offers to purchase NL Industries' chemical unit for \$732 million. **Page 6**

■ Several chemists are among new members elected by National Academy of Sciences. **Page 6**

Cover: Computer graphics-generated model of yeast cytochrome c-yeast cytochrome c peroxidase complex. The structure was calculated by V. R. Lum, Life Sciences Research Labs, Eastman Kodak Co.

Letters **2**

Editor's Page **3**

Concentrates

Business **7**

Government **15**

Science/Technology **18**

The Departments

Meetings **28**

Newscrips **48**

Business

Most of 100 largest U.S. chemical producers posted higher sales and increased operating profits in 1986. **Page 9**

Government

Reduced 1988 R&D funding for federal agencies is one of several proposals being considered by Congress. **Page 16**

Science

Although the rise in atmospheric methane has been firmly established, pinning down the causes poses difficult problems. **Page 22**

Newly discovered bacterium secretes cellulase enzyme system that exhibits activity and stability above 70 °C. **Page 23**

Education

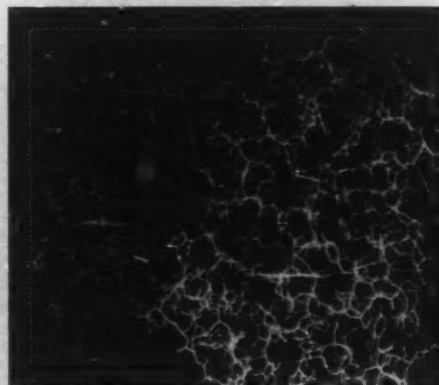
More diversity in graduate program urged for doctorate in analytical chemistry. **Page 25**

Technology

Capabilities of molecular modeling systems increased by introduction of new hardware and software. **Page 26**

Use of ion implantation to raise conductivity of polymers may lead to improvements in current semiconductor materials. **Page 27**

High-temperature membrane to separate gases prepared by in-situ polymerization of polydimethylsiloxane in a porous glass. **Page 27**



Cover Story

Understanding of biological electron transfer enhanced by research to clarify distance dependence of electron transfer rates, and effects of donor-acceptor separation and energetics of reaction. **Page 19**

Sales, Profits Increase for Most Top 100 Chemical Producers

Of 100 largest companies, 58 posted higher sales and 53 increased profits in 1986; restructuring accounted for many of the shifts in ranking

William J. Storck, C&EN New York

C&EN's ranking of the 100 largest chemical producers in the U.S., based on 1986 chemical sales, reflects the improving performance of the chemical industry last year, compared with 1985. The industry's sales increased slightly as many of its major markets firmed, and chemical prices started to move up, although just slightly, from a long-standing plateau. Among the Top 100 chemical producers, in fact, the only consistently poor results in 1986 were for those companies with large stakes in agricultural chemicals, which were pulled down by the beleaguered farm economy.

Of the Top 100 chemical producers, the ranking for which is compiled from corporate annual reports and interviews with companies not issuing annual reports, 58 posted increases in chemical sales for 1986, and 41 registered declines. One company, Huntsman Chemical, was newly formed in 1986, thus no comparison is possible with the year before. The 41 instances of sales declines may seem like a large percentage, but it is a marked improvement over 1985's ranking, when 54 of the Top 100 posted decreases in chemical sales.

The number of companies with larger chemical sales in 1986 was fairly evenly divided between the 50 larger firms on the list and the 50 smaller companies. Of the 50 larger ones, 30 had sales increases, and

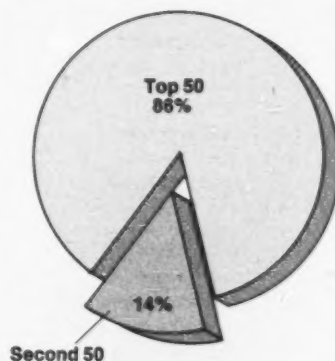
of the smaller producers, 28 had increases.

Operating profits for the Top 100 also improved last year, compared with 1985. Of the 82 companies that reported operating profits, 53 posted increases and 23 posted declines. Four of the firms registered deficits for the year, thus change in operating profits is not figured for them. In the 1985 ranking, 50 of the companies that reported operating profits posted declines from the year before.

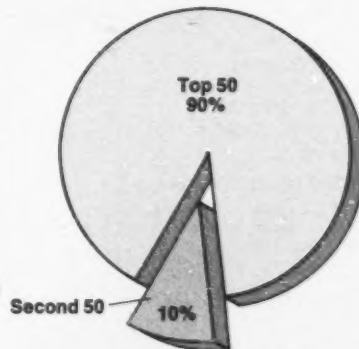
Of the 43 of the 50 larger firms that reported operating profits for 1986, 35 had increases. Of the 39 of the 50 smaller firms that reported operating profits, just 18 had increases. Within this group, however, are a number of fertilizer producers whose earnings are not buffered by other, more profitable products.

Within the 100 firms, very few remained at the same ranking as the previous year. Even among the 10 largest companies, there were changes as firms bought, sold, and

Large firms dominate both sales and earnings...

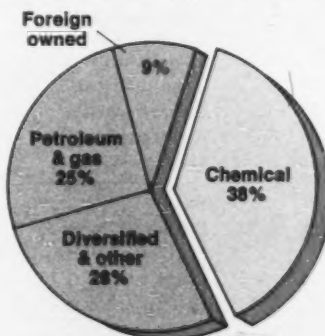


1986 sales = \$128 billion

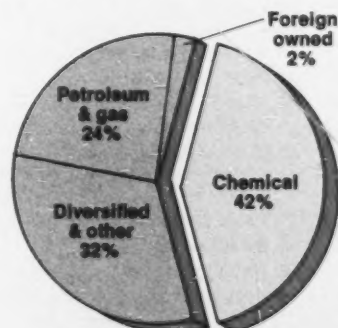


1986 operating profits = \$13.9 billion

...and chemical firms lead other types of producers



1986 sales = \$128 billion



1986 operating profits = \$13.9 billion

Restructurings continue to change Top 100 sales rankings

Rank 1986 1985		Chemical sales 1986 (\$ millions)	Change from 1985	Chemical sales as % of total sales	Industry classification	Chemical operating profits ^a (\$ millions)	Change from 1985	Chemical operating profits as % of total operating profits	Operating profit margin ^b	Identifiable chemical assets (\$ millions)	Chemical assets as % of total assets	Operating return on chemical assets ^c
1	1 Du Pont	\$11,839	5.2%	43.6%	Diversified	\$1764	102.8%	52.1%	14.9%	\$8739	36.2%	20.2%
2	2 Dow Chemical	8,863	-6.8	79.8	Basic chemicals	976	138.0	76.1	11.0	8139	66.5	12.0
3	3 Exxon	6,079	-8.9	8.1	Petroleum	817	112.2	9.9	13.4	5508	7.9	14.8
4	5 Union Carbide	5,001	26.3	75.8	Basic chemicals	748	81.1	94.6	15.0	5047	74.3	14.8
5	6 Atlantic Richfield	4,915	29.2	32.8	Petroleum	398	445.2	64.7	8.1	2085	9.7	19.1
6	4 Monsanto	4,701 ^d	-9.6	58.3	Basic chemicals	896	87.8	141.1	19.1	3860	46.7	23.2
7	12 BASF	3,600 ^d	38.5	100.0	Basic chemicals	na	na	na	na	na	na	na
8	7 Shell Oil	3,292	-0.8	19.6	Petroleum	646	292.7	35.1	19.7	3447	13.1	18.8
9	9 Amoco	2,928	0.8	14.5	Petroleum	467	-1.3	23.0	15.9	2545	11.0	18.3
10	8 Celanese	2,891	-5.1	100.0	Basic chemicals	258	103.1	100.0	8.9	na	na	na
11	17 Allied-Signal	2,819	37.2	23.9	Diversified	346	77.4	32.9	12.3	2161	19.2	16.0
12	10 W. R. Grace	2,492	-13.1	66.9	Specialty chemicals	285	21.8	1187.5	11.4	1633	53.1	17.5
13	13 Eastman Kodak	2,379	1.3	20.6	Photo equipment	227	24.0	31.4	9.5	2266	17.6	10.0
14	11 Chevron	2,378	-8.9	9.1	Petroleum	147	def	20.6	6.2	3207	9.3	4.6
15	15 Mobil	2,351	3.8	3.9	Petroleum	57	-29.6	1.1	2.4	2021	5.4	2.8
16	14 General Electric	2,331	-0.7	6.3	Diversified	424	-9.0	9.8	18.2	3602	10.4	11.8
17	22 Occidental Petroleum	2,088 ^e	28.8	13.0	Petroleum	176	75.1	36.2	8.4	2393	13.7	7.3
18	18 Rohm & Haas	2,067	5.1	100.0	Basic chemicals	280	3.7	100.0	13.5	1470	100.0	19.0
19	19 American Cyanamid	1,821	-0.5	47.7	Basic chemicals	135	66.8	38.3	7.4	1275	49.6	10.6
20	21 Air Products ^f	1,798	7.4	90.7	Basic chemicals	363	16.2	129.4	20.2	2173	80.3	16.7
21	23 Mobay	1,710	6.9	100.0	Basic chemicals	190	-6.4	100.0	11.3	1246	100.0	16
22	20 Hercules	1,709	-2.0	65.4	Basic chemicals	101	114.9	49.5	5.9	1484	71.6	6.9
23	15 Phillips Petroleum	1,698	-25.1	17.0	Petroleum	299	36.5	30.3	17.6	1053	8.5	28.4
24	25 Borden	1,638	7.0	32.7	Dairy products	176	36.4	35.3	10.7	1399	40.3	12.6
25	24 Ciba-Geigy	1,490	-3.2	61.3	Specialty chemicals	na	na	na	na	na	na	na
26	26 Ashland Oil	1,477	-1.5	20.3	Petroleum	71	4.4	15.0	4.8	527	13.9	13.5
27	27 B. F. Goodrich	1,458	5.4	57.1	Rubber products	134	68.5	79.9	9.2	1199	82.5	11.1
28	29 FMC	1,399	11.0	46.6	Machinery	224	56.8	71.6	16.0	1344	50.0	16.7
29	28 American Hoechst	1,331 ^d	-2.2	77.8	Basic chemicals	na	na	na	na	na	na	na
30	31 Texaco	1,279	4.8	4.0	Petroleum	91	658.3	3.9	7.1	1114	3.2	8.2
31	30 Ethyl	1,272	2.5	57.0	Basic chemicals	247	24.8	69.0	19.4	829	48.4	29.8
32	34 Olin	1,114	-2.9	65.3	Basic chemicals	80	72.7	50.3	7.2	840	59.6	9.5
33	37 National Distillers	1,087	4.7	62.8	Alcoholic beverages	124	72.6	67.0	11.4	1385	47.7	8.9
34	40 Dow Corning	1,085	20.4	100.0	Specialty chemicals	111 ^g	16.2	100.0	10.2	na	na	na
35	36 International Minerals ^h	1,077	1.9	67.1	Agrochemicals	35	-74.2	57.1	3.2	2042	84.1	1.7
36	41 National Starch	1,064	20.7	100.0	Specialty chemicals	140	22.4	100.0	13.2	743	100.0	18.9
37	32 Unocal	1,058	-13.2	12.6	Petroleum	46 ^o	-20.7	26.1	4.4	722	7.1	6.4
38	38 Borg-Warner	1,043	12.3	30.9	Auto equipment	153	25.3	43.8	14.7	562	23.6	27.3
39	44 Lubrizol	889	10.6	91.0	Specialty chemicals	140	49.5	108.6	15.7	589	67.1	23.7
40	42 PPG Industries	843 ^o	0.2	18.0	Glass products	103	28.3	14.8	12.2	1185	25.5	8.7
41	85 Aluminum Co. of America	840 ^d	209.6	18.0	Nonferrous metals	na	na	na	na	na	na	na
42	51 Pennwalt	777	14.2	70.1	Basic chemicals	93	57.3	78.8	12.0	649	73.8	14.3
43	49 Cabot ⁱ	769	7.9	58.7	Specialty metals	138	55.9	69.3	17.9	494	32.7	27.9
44	39 CF Industries	766	-16.8	100.0	Agrochemicals	-45	def	def	def	842	100.0	def
44	43 Reichhold Chemicals	766	-6.9	100.0	Basic chemicals	53	150.7	100.0	7.0	458	100.0	11.6
46	— Aristech	751	-4.9	100.0	Steel	98	131.5	100.0	13.0	na	na	na
47	50 Nalco Chemical	736	7.9	100.0	Specialty chemicals	108	-11.0	100.0	14.7	586	100.0	18.4
48	58 NL Industries	734	30.1	57.2	Petroleum services	na	na	na	na	na	na	na
49	48 Eli Lilly	699	-2.0	18.8	Drugs	53	-39.8	5.8	7.6	766	16.7	6.9
50	54 Engelhard	686	11.3	29.1	Specialty metals	77	24.2	80.5	11.6	607	58.2	12.7

Rank 1986 1985	Chemical sales 1986 (\$ millions)	Change from 1985	Chemical sales as % of total sales	Industry classification	Chemical operating profits ^a (\$ millions)	Change from 1985	Chemical operating profits as % of total operating profits	Operating profit margin ^b	Identifiable chemical assets (\$ millions)	Chemical assets as % of total assets	Operating return on chemical assets ^c
51 53 Morton Thiokol ^h	\$652	5.8%	33.4%	Diversified	\$ 87	-2.6%	33.9%	13.4%	\$580	43.1%	15.1%
52 56 Terra Chemicals	626	9.0	100.0	Agrochemicals	na	na	na	na	na	na	na
53 64 International Flavors	621	23.9	100.0	Specialty chemicals	144	22.8	100.0	23.3	673	100.0	21.5
54 45 Williams Cos.	613	-17.4	33.0	Agrochemicals	na	na	na	na	na	na	na
55 52 Koppers	589	-4.8	42.2	Diversified	40	def	25.9	6.7	342	33.6	11.6
56 47 Farmland Industries	574	-20.4	21.1	Agricultural supplies	-38	def	def	def	342	45.8	def
57 — Huntsman Chemical	570	na	100.0	Basic chemicals	na	na	na	na	na	na	na
58 61 Vista Chemicals ⁱ	550	5.5	100.0	Basic chemicals	91	na	100.0	16.5	na	na	na
58 62 Solvay America	550	6.6	100.0	Basic chemicals	na	na	na	na	na	na	na
60 56 Witco	544 ^g	-5.2	40.1	Specialty chemicals	45	-21.3	34.0	8.2	275	33.6	16.2
61 63 Polysar	536	4.4	100.0	Basic chemicals	na	na	na	na	na	na	na
62 67 H. B. Fuller ⁱ	528	15.5	100.0	Specialty chemicals	39	26.5	100.0	7.5	291	100.0	13.6
63 66 Liquid Air	491	6.9	86.0	Basic chemicals	59	2.2	97.5	12.0	595	83.0	9.9
64 59 Standard Oil	475	-13.9	4.7	Petroleum	11	-59.3	1.5	2.3	347	2.2	3.2
65 65 Kerr-McGee	456	-5.7	18.0	Petroleum	14	-69.6	54.4	3.1	na	na	na
66 — CBI Industries	451	2.6	39.0	Construction	60	-4.5	95.9	13.3	552	47.3	10.9
67 71 American Petrofina	441	9.0	22.5	Petroleum	53	358.4	def	12.0	250	14.5	21.3
68 — Henley Group	435	14.5	13.7	Basic chemicals	60	def	def	13.6	359	7.6	16.7
69 74 Pfizer	416	6.0	9.3	Drugs	41	137.4	4.0	9.8	439	8.5	9.2
70 75 Tyler	386	3.4	40.4	Diversified chemicals	27	-8.9	51.1	7.0	187	37.2	14.5
71 73 Rhône-Poulenc	380	-5.0	100.0	Specialty chemicals	na	na	na	na	na	na	na
72 76 GAF	378	3.6	50.1	Specialty chemicals	108	16.4	77.5	28.6	252	18.7	42.8
73 68 Freeport-McMoRan	374	-17.1	59.4	Agrochemicals	76	-26.2	def	20.2	244	10.3	31.0
74 69 Merck	359	-20.3	8.7	Drugs	50	-14.4	4.8	13.9	431	11.7	11.6
75 79 Betz Laboratories	344	7.8	100.0	Specialty chemicals	63	4.6	100.0	18.4	270	100.0	23.5
76 72 Sun Co.	317	-21.1	3.0	Petroleum	na	na	na	na	na	na	na
77 77 Chemed	314	-6.6	87.4	Specialty chemicals	33	-23.8	82.7	10.5	162	82.6	20.3
78 84 Union Camp	305	10.9	14.9	Diversified	6	-30.3	2.6	2.0	227	8.3	2.7
79 83 Great Lakes Chemical	300	6.5	100.0	Specialty chemicals	43	-5.9	100.0	14.2	na	na	na
80 86 Ferro	286 ^d	6.8	39.4	Specialty materials	22	62.0	37.4	7.8	162	41.4	13.7
81 90 Loctite	267	15.3	100.0	Specialty chemicals	37	5.5	100.0	13.8	244	100.0	15.1
82 — Henkel	265	-8.0	100.0	Specialty chemicals	na	na	na	na	na	na	na
83 89 Stepan	260	10.1	100.0	Specialty chemicals	14	51.7	100.0	5.4	153	100.0	9.2
84 88 Kaiser Aluminum	254	-0.1	11.5	Nonferrous metals	34	333.3	60.0	13.3	284	8.8	11.9
84 81 Petrolite ⁱ	254	-12.5	90.7	Specialty chemicals	23	-36.8	94.6	9.0	158	68.8	14.4
84 80 Vulcan Materials	254	-13.2	26.5	Nonmetallic minerals	19	-19.9	12.1	7.7	na	na	na
87 91 Lonza	252	27.9	100.0	Specialty chemicals	na	na	na	na	na	na	na
88 82 Dexter	245	-12.9	37.6	Rubber products	23	-17.4	30.3	9.5	162	62.6	14.4
89 78 Mississippi Chemical ^h	228	-30.0	100.0	Farm cooperative	-13	def	def	def	265	100.0	def
90 95 Sigma-Aldrich	199	20.9	76.8	Specialty chemicals	53	11.5	84.4	26.4	207	84.4	25.5
91 93 Essex Chemical	184	6.8	89.4	Basic chemicals	32	0.0	115.3	17.4	105	76.3	30.5
92 99 Crompton & Knowles	165	46.1	77.2	Specialty chemicals	15	19.4	65.1	9.0	94	83.5	15.8
93 92 Georgia-Pacific	155	-10.4	2.1	Wood products	na	na	na	na	na	na	na
94 97 First Mississippi	153	1.2	56.6	Agrochemicals	20	-36.3	def	13.0	67	26.1	29.6
95 96 Agway	143	-11.6	4.1	Farm cooperative	na	na	na	na	na	na	na
96 — Quaker Chemical	128	4.4	100.0	Specialty chemicals	14	11.3	100.0	10.8	99	100.0	14.0
97 98 UGI	113	-3.9	25.4	Natural gas	0	def	def	def	168	28.8	def
98 — LeaRonai	105	-19.5	100.0	Specialty chemicals	10	-26.1	100.0	9.8	65	100.0	15.8
99 100 Lawter Chemicals	104	7.0	100.0	Diversified	20	49.0	100.0	19.0	93	100.0	21.1
100 — Products Research & Chemical	83	10.4	90.2	Specialty chemicals	16	18.3	62.9	18.7	53	82.7	29.5

^a Operating profit is sales less administrative expenses and cost of sales. ^b Operating profit from chemicals as a percentage of chemical sales. ^c Chemical operating profit as a percentage of identifiable chemical assets. ^d Chemical sales include significant amounts of nonchemical products. ^e Does not include all chemical sales. ^f Fiscal year ends Sept. 30. ^g Chemical net profits. ^h Fiscal year ends June 30. ⁱ Fiscal year ends Nov. 30. ^j Fiscal year ends Oct. 31. na = not available. def = deficit.

C&EN's five-way ranking of the Top 100 chemical producers

	Chemical sales			Chemical operating profits			Chemical operating profit margin			Identifiable chemical assets			Return on chemical assets		
	Rank			Rank			Rank			Rank			Rank		
	1986	1985	1984	1986	1985	1984	1986	1985	1984	1986	1985	1984	1986	1985	1984
\$ Millions															
Agway	\$ 143	95	96	na	—	—	na	—	—	na	—	—	na	—	—
Air Products	1,798	20	21	\$ 363	9	8	20.2%	4	10	\$2173	12	16	16.7%	28	24
Allied-Signal	2,819	11	17	346	10	13	12.3	36	39	2161	13	15	16.0	30	44
Aluminum Co. of America	840	41	85	na	—	—	na	—	—	na	—	—	na	—	—
American Cyanamid	1,821	19	19	135	27	34	7.4	63	64	1275	23	25	10.6	56	57
American Hoechst	1,331	29	28	na	—	—	na	—	—	na	—	—	na	—	—
American Petrofina	441	67	71	53	46	71	12.0	38	73	250	59	61	21.3	15	69
Amoco	2,926	9	9	467	7	3	15.9	18	15	2545	9	10	18.3	24	15
Aristech	751	46	—	98	34	—	13.0	34	—	na	—	—	na	—	—
Ashland Oil	1,477	26	26	71	42	40	4.8	72	63	527	44	50	13.5	45	32
Atlantic Richfield	4,915	5	8	na	—	—	na	—	—	2085	14	11	19.1	19	—
BASF	3,600	7	12	na	—	—	na	—	—	na	—	—	na	—	—
Betz Laboratories	344	75	79	63	43	43	18.4	11	9	270	56	64	23.5	12	10
Borden	1,638	24	25	176	19	19	10.7	47	44	1399	20	21	12.6	47	46
Borg-Warner	1,043	36	36	153	21	22	14.7	22	22	562	42	54	27.3	9	7
Cabot	769	43	49	138	26	32	17.9	13	27	494	45	52	27.9	8	19
CBI Industries	451	66	—	60	44	—	13.3	31	—	552	43	—	10.9	55	—
Celanese	2,891	10	8	258	14	20	8.9	56	67	na	—	9	na	—	63
CF Industries	766	44	39	45	82	80	def	—	—	842	29	30	def	—	—
Chemed	314	77	77	33	62	55	10.5	48	24	162	66	72	20.3	17	8
Chevron	2,378	14	11	147	22	84	6.2	69	—	3207	8	8	4.6	69	—
Ciba-Gelgy	1,490	25	24	na	—	—	na	—	—	na	—	—	na	—	—
Crompton & Knowles	165	92	99	15	72	71	9.0	54	32	94	73	81	15.8	31	20
Dexter	245	88	82	23	65	63	9.5	51	35	162	66	74	14.4	39	17
Dow Chemical	8,863	2	2	978	2	6	11.0	45	66	8139	2	1	12.0	48	61
Dow Corning	1,085	34	40	na	—	—	na	—	—	na	—	—	na	—	—
Du Pont	11,839	1	1	1,764	1	1	14.9	21	49	8739	1	2	20.2	18	40
Eastman Kodak	2,379	13	13	227	16	14	9.5	51	48	2266	11	12	10.0	57	50
Eli Lilly	699	49	48	53	48	32	7.6	61	27	766	32	32	6.9	66	41
Engelhard	666	50	54	77	40	42	11.6	41	33	607	37	49	12.7	46	36
Essex Chemical	184	91	93	32	63	59	17.4	15	10	105	71	79	30.5	3	4
Ethyl	1,272	31	30	247	15	12	19.4	7	16	829	31	35	29.8	4	9
Exxon	6,079	3	3	817	4	7	13.4	29	58	5508	3	3	14.8	36	53
Farmland Industries	574	56	47	38	81	77	def	—	78	342	51	55	def	—	75
Ferro	286	80	86	22	67	69	7.8	59	59	162	66	75	13.7	43	46
First Mississippi	153	94	97	20	68	60	13.0	34	7	67	75	82	29.6	5	2
FMC	1,399	28	29	224	17	17	16.0	17	31	1344	22	24	16.7	26	38
Freeport-McMoRan	374	73	68	76	41	26	20.2	4	5	244	60	68	31.0	2	1
H. B. Fuller	528	62	67	39	58	57	7.5	62	53	291	53	65	13.6	44	33
GAF	376	72	76	108	30	29	28.6	1	2	252	58	67	42.6	1	3
General Electric	2,331	16	14	424	8	4	18.2	12	8	3602	6	7	11.8	50	35
Georgia-Pacific	155	93	92	na	—	—	na	—	—	na	—	—	na	—	—
B. F. Goodrich	1,456	27	27	134	28	37	9.2	53	57	1199	25	27	11.1	54	55
W. R. Grace	2,492	12	10	285	12	10	11.4	42	46	1633	17	14	17.5	25	36
Great Lakes Chemical	300	79	83	43	55	54	14.2	24	14	na	—	—	na	—	—
Henkel	265	62	—	na	—	—	na	—	—	na	—	—	na	—	—
Henley Group	435	68	—	60	44	—	13.8	26	—	359	49	—	16.7	26	—
Hercules	1,709	22	20	101	33	50	5.9	70	74	1464	19	19	6.9	66	71
Huntsman Chemical	570	57	—	na	—	—	na	—	—	na	—	—	na	—	—
International Flavors	621	53	64	144	23	25	23.3	3	4	673	35	44	21.5	14	14

\$ Millions	Chemical sales			Chemical operating profits			Chemical operating profit margin			Identifiable chemical assets			Return on chemical assets		
	Rank			Rank			Rank			Rank			Rank		
	1986	1985	1984	1986	1985	1984	1986	1985	1984	1986	1985	1984	1986	1985	1984
International Minerals	\$1,077	35	34	\$ 35	60	18	3.2%	74	25	\$2042	15	23	1.7%	73	42
Kaiser Aluminum	254	84	88	34	61	76	13.3	31	72	284	54	62	11.9	49	72
Kerr-McGee	456	65	65	14	73	50	3.1	75	37	na	—	43	na	—	51
Koppers	589	55	52	40	57	83	6.7	68	—	342	51	58	11.6	51	—
Lawler International	104	99	100	20	68	70	19.0	9	19	93	74	80	21.1	16	27
LeaRonald	105	98	—	10	77	—	9.8	49	—	65	76	—	15.8	31	—
Liquid Air	491	63	66	59	46	46	12.0	38	28	595	38	—	9.9	58	—
Locliffe	267	81	90	37	59	57	13.8	26	17	244	60	66	15.1	34	25
Lonza	252	87	91	na	—	—	na	—	—	na	—	—	na	—	—
Lubrizol	889	39	44	140	24	29	15.7	19	30	589	39	39	23.7	11	28
Merck	359	74	69	50	52	46	13.9	25	23	431	48	59	11.6	51	26
Mississippi Chemical	228	89	78	—13	80	77	def	—	77	265	57	60	def	—	74
Mobay	1,710	21	23	193	18	16	11.3	44	41	1246	24	26	15.4	33	34
Mobil	2,351	15	15	57	47	34	2.4	76	70	2021	16	13	2.8	71	68
Monsanto	4,701	6	4	896	3	2	19.1	8	42	3860	5	5	23.2	13	39
Morton Thiokol	652	51	53	87	38	31	13.4	29	18	580	41	47	15.1	34	23
Nalco Chemical	736	47	50	108	30	22	14.7	22	12	586	40	48	18.4	23	11
National Distillers	1,087	33	35	124	29	39	11.4	42	52	1385	21	36	8.9	62	46
National Starch	1,064	36	41	140	24	41	13.2	33	50	743	33	37	18.9	21	43
NL Industries	734	48	58	na	—	20	na	—	6	na	—	57	na	—	5
Occidental Petroleum	2,088	17	22	176	19	28	8.4	57	54	2393	10	18	7.3	65	58
Olin	1,114	32	33	80	39	53	7.2	64	68	840	30	31	9.5	59	60
Pennwalt	777	42	51	93	35	45	12.0	38	43	649	36	38	14.3	41	45
Petrolite	254	84	81	23	65	56	9.0	54	27	158	69	71	14.4	39	13
Pfizer	416	69	74	41	56	68	9.8	49	64	439	47	56	9.2	60	64
Phillips Petroleum	1,698	23	15	299	11	11	17.6	14	37	1053	28	22	28.4	7	22
Polysar	536	61	63	na	—	—	na	—	—	na	—	—	na	—	—
PPG Industries	843	40	42	103	32	36	12.2	37	39	1185	26	28	8.7	63	54
Products Research & Chemical	83	100	—	16	71	—	18.7	10	—	53	77	—	29.5	6	—
Quaker Chemical	128	96	—	14	73	—	10.8	46	—	99	72	—	14.0	42	—
Reichhold Chemicals	786	44	43	53	48	66	7.0	66	75	458	46	51	11.6	51	64
Rhône-Poulenc	380	71	73	na	—	—	na	—	—	na	—	—	na	—	—
Rohm & Haas	2,067	18	18	280	13	9	13.5	28	19	1470	18	20	19.0	20	16
Shell Oil	3,292	8	7	648	6	15	19.7	6	80	3447	7	6	18.8	22	67
Sigma-Aldrich	199	90	95	53	48	50	26.4	2	1	207	63	73	25.5	10	6
Solvay America	550	58	62	na	—	—	na	—	—	na	—	—	na	—	—
Standard Oil	475	64	59	11	76	64	2.3	77	61	347	50	46	3.2	70	62
Stepan	260	83	89	14	73	74	5.4	71	69	153	70	76	9.2	60	56
Sun Co.	317	76	72	na	—	—	na	—	—	na	—	—	na	—	—
Terra Chemicals	626	52	56	na	—	—	na	—	—	na	—	—	na	—	—
Texaco	1,279	30	31	91	36	71	7.1	65	76	1114	27	29	8.2	64	73
Tyler	388	70	75	27	64	62	7.0	66	47	187	64	70	14.5	38	21
UGI	113	97	98	0	79	79	def	—	79	168	65	77	def	—	76
Union Carbide	305	78	84	6	78	74	2.0	78	71	227	62	69	2.7	72	64
Union Carbide	5,001	4	5	748	5	5	15.0	20	33	5047	4	4	14.8	36	49
Unocal	1,058	37	32	46	53	46	4.4	73	82	722	34	34	6.4	68	52
Vista Chemical	550	58	61	91	37	—	10.5	16	—	na	—	—	na	—	—
Vulcan Materials	254	84	80	19	70	65	7.7	60	45	na	—	—	na	—	—
Williams Cos.	613	54	45	na	—	62	na	—	—	na	—	45	na	—	—
Witco	544	60	58	45	54	49	6.2	56	36	275	55	63	16.2	29	12

Note: Companies with negative profitability and those giving only net profits are not ranked. There are 82 firms ranked for operating profits, 78 for operating profit margin, 77 for chemical assets, and 73 for return on assets for 1986. na = not available. def = deficit.

closed down businesses. However, the three largest chemical producers—Du Pont, Dow Chemical, and Exxon—remained first, second, and third, respectively; beyond that, companies began to shift positions. Union Carbide, which had ranked fifth in 1985, moved up to fourth, a rank it has not held since 1981. And Atlantic Richfield rose to fifth place from sixth in 1985. Monsanto, which had ranked fourth from 1985 chemical sales, dropped to sixth in 1986 as the company sold off some of its chemical operations.

BASF Corp., the U.S. arm of West Germany's BASF, rose to seventh place from 12th in 1985 as results from recently acquired companies such as Enka and Inmont began to be felt. Shell Oil, however, fell to eighth place from ninth, partly owing to divestiture. Amoco remained in ninth place, the same as in 1985, and Celanese dropped to 10th place from eighth the year before. For the 1986 ranking, Celanese and American Hoechst are treated as separate companies since they were independent throughout the entire year (but merged at the beginning of this year).

As in each year's Top 100 ranking, companies in the 1986 list are compared with what their rankings were one year ago rather than what they would have been based on restated results in the current year annual report. Thus, a rise or fall in rank may well reflect acquired or divested chemical businesses during the year as well as increasing or decreasing sales from operations.

Eight companies are new to the list this year. The largest of these is Aristech at 46th place. This is the former chemical operations of USX Corp. that were spun off last year and formed into a separate publicly traded company. Huntsman Chemical, also new at 57th place, has as its core the former styrenics business of American Hoechst. CBI Industries, which is ranked 66th, has as its chemical operations the Liquid Carbonics industrial gas business, acquired from Enron, which has been removed from the list because it no longer is a chemical producer.

Henkel Corp., in 82nd place, is not new to the list but reappears after being off the rankings for 1985

when it did not break out its U.S. sales. Three companies, Quaker Chemical at 96th, LeaRonald at 98th, and Products Research & Chemical at 100th, have moved onto the list as a result of sales growth and other companies' having dropped off the list because of divested chemical operations.

Besides Enron, other companies that have dropped off the Top 100 listing this year are Big Three Industries, acquired by Liquid Air; Chesebrough-Pond's, acquired by Unilever; Emhart, which has reorganized and no longer breaks out chemical sales in its annual report (efforts to reach the company were unsuccessful); Millmaster Onyx, which has sold its operations in a leveraged buyout; SCM, acquired by Hanson Trust; USX Corp., which spun off its chemical operations to form Aristech; and Williams Cos., which has sold its Agrico fertilizer operations to Freeport-McMoRan.

As usual, some companies that have large chemical operations do not appear on the list. Some of the more outstanding examples are such U.S.-based firms as 3M and Procter & Gamble; privately held companies such as J. M. Huber; and foreign-owned companies with U.S. operations such as Imperial Chemical Industries' ICI Americas and Schering A.G.'s Sherex Chemical.

The rankings of the largest chemical producers remain less precise than desired, because C&EN must by and large rely on the data supplied by the companies themselves, and the definition of what is a chemical or where to include chemical operations varies widely from company to company. Those data can include nonchemical operations in some firms such as Monsanto, Aluminum Co. of America, and BASF Corp. Other firms, such as Witco, PPG Industries, and Occidental Petroleum, have significant chemical operations that are hidden within divisions other than those that they decide to call chemical.

Besides the sales rankings, C&EN rates the 100 largest chemical producers four other ways, by chemical operating profits, operating profit margin (chemical operating profits as a percentage of chemical sales), identifiable chemical assets, and re-

turn on chemical assets (chemical operating profits as a percentage of identifiable chemical assets).

As in chemical sales (\$11.8 billion in 1986), Du Pont was number one in chemical operating profits with a total of \$1.76 billion. Dow Chemical ranks second with \$978 million in chemical operating profits, up from sixth place in 1985. Monsanto, at third with \$896 million, dropped from second in 1985. Fourth-place Exxon had chemical operating profits of \$817 million and was up from seventh in 1985. And Union Carbide, with chemical operating profits of \$748 million, was fifth, the same as in 1985.

The top-ranking company for chemical operating profit margin was GAF, with a return of 28.6%, up from second in 1985. Sigma-Aldrich ranked second with a return of 26.4%; it fell from first place in 1985. Ranked third is International Flavors & Fragrances with a return of 23.3%. IFF held fourth place the year before. Air Products and Freeport-McMoRan tied for fourth place with an operating profit margin of 20.2%. In 1985, Air Products had ranked 10th and Freeport had been fifth.

Du Pont ranked first in identifiable chemical assets with \$8.74 billion, and Dow ranked second with \$8.14 billion. This is a reversal of their rankings in 1985. Exxon ranked third with \$5.51 billion, the same rank as the previous year. Fourth, and the same rank as in 1985, was Union Carbide at \$5.05 billion. And Monsanto was fifth with identifiable chemical assets of \$3.86 billion. Monsanto also had been fifth the previous year.

As with operating profit margin, GAF ranked first in return on identifiable chemical assets with 42.8%. This is up from third in 1985. Freeport-McMoRan ranked second with a return of 31.0%. In 1985, Freeport had been first. Essex Chemical ranked third, up from fourth in last year's ranking, with its return on chemical assets of 30.5%. Ethyl ranked fourth with a return of 29.8%, and was up from ninth place in 1985. And in fifth place was First Mississippi, with a return on chemical assets of 29.6%. In 1985, First Mississippi had ranked second. □

Rise in atmospheric methane probed

Systematic global measurements have firmly established that the concentration of methane in the atmosphere is increasing about 1% per year. Last month at the American Chemical Society meeting in Denver, an interdisciplinary group of scientists gathered to try to understand why.

Pinning down responsibility for the increase is a difficult problem, as methane is formed both by thermocatalytic reactions in Earth's crust and by many bacteria. Scientists working in atmospheric chemistry, microbiology, biogeochemistry, stable-isotope chemistry, and radiocarbon dating met and exchanged ideas at a five-day symposium sponsored by the Division of Geochemistry. Researchers from the various disciplines aimed to give each other an appreciation of the possibilities and limitations of the various approaches to the complex problem, according to symposium organizer Ronald S. Oremland, a microbial geochemist with the U.S. Geological Survey.

The increase in methane is a concern because methane is a greenhouse gas that traps infrared radiation emitted by Earth's surface. Climate models predict the accumulation of methane and other greenhouse gases like carbon dioxide and chlorofluorocarbons is leading inexorably to a global warming. On a molecule-per-molecule basis, methane is a more important greenhouse gas than carbon dioxide, says F. Sherwood Rowland, professor of chemistry at the University of California, Irvine. That's so, he says, because methane is 20 times more efficient at trapping infrared radiation.

Rowland's research group has been measuring methane and other trace gases in the atmosphere over a wide range of latitudes since 1978. "The average concentration at the beginning of 1987 was 1.68 ppm, about 10% higher than when we began taking measurements," says Irvine chemist Donald R. Blake—an average increase of about 1% per year.

That rate of increase has been fairly steady for almost 200 years, according to M. Aslam K. Khalil, a physicist with the Oregon Graduate Center's Institute of Atmospheric Sciences in Beaverton. Analysis of air samples trapped in polar ice cores shows that from about 4000 years ago until 200 years ago, methane concentrations hovered around 700 ppb. Khalil and his collaborator, Reinhold A. Rasmussen, also at the Oregon Graduate Center, think that about half of the annual emissions are from natural sources. The other half are related to agricultural and industrial sources that have been increasing as the world's population has increased.

Oil and gas exploitation is one source of methane that is related to human activity. Studies of the carbon-14 content of atmospheric methane, however, indicate that at least 80% must have a biological, as opposed to fossil fuel, origin.

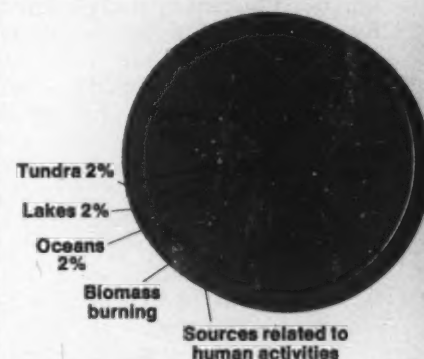
Bacteria produce methane by anaerobic fermentation in wet locations where oxygen is scarce: peat bogs, swamps, other natural wetlands, paddies, and the intestinal tracts of cattle and termites. The number of cattle in the world has increased from about 800 million in 1950 to about 1.3 billion today, Khalil notes. He also points out that multiple cropping of rice has become more common, so paddies are flooded for a greater part of the year than they once were.

The increase in methane also may be caused in part by rising levels of carbon monoxide from combustion processes. Both methane and carbon monoxide are removed from the atmosphere largely by reaction with hydroxyl radicals. With both gases competing for a limited amount of hydroxyl, the average lifetime of methane molecules before they are destroyed may be getting longer.

"We need more work on the important details of the sources, sinks, and atmospheric chemistry of methane," says Khalil. "Better assignments of contributions from individual sources and the distribution of those sources globally will let us make better projections for the future."

Among many projects aimed at just those goals that were described

Wetlands and paddies yield almost half of all methane



Sources: M. A. K. Khalil and R. A. Rasmussen, Oregon Graduate Center, Beaverton

at the symposium are experiments that use the $^{13}\text{C}/^{12}\text{C}$ isotope ratio of methane to try to ascertain where the gas is coming from. Atmospheric scientist Stanley C. Tyler and his coworkers at the National Center for Atmospheric Research in Boulder are measuring the stable isotope content of methane from different sources.

Using an isotope-ratio mass spectrometer, they find the isotope ratio of methane varies with its source. For example, Tyler finds that methane collected from termite mounds contains from 54 to 58 parts per thousand less carbon-13 than a reference standard of carbonate rock. Methane collected from swamps and marshes in temperate and tropical locations contains from 48 to 69 parts per thousand less carbon-13 than the standard. However, atmospheric methane on the average is depleted in carbon-13 by about 47 parts per thousand. The researchers are trying to come up with a weighted sum of values from the various sources and sinks that will equal the average $^{13}\text{C}/^{12}\text{C}$ ratio of atmospheric methane.

"One good thing about isotope ratios is they will help us understand the mechanism of consumption and production of methane," says Tyler. "We now have ballpark figures for a lot of sources. We need to characterize a few areas in depth, so then we can extrapolate to other areas with similar environmental conditions."

Pamela Zurer, Washington

First-quarter earnings
rise for most chemical companies
Page 20

MAY 11, 1987

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5/12/87

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SUPERCONDUCTIVITY

An electrical revolution
in the making
Page 7

News of the Week

■ **Gordon Cain, with the \$471 million purchase of Du Pont's high-density polyethylene business, moves closer to establishing a new petrochemical empire.** Page 4

■ **Government, industry, and environmental groups differ sharply over international proposals to regulate chlorofluorocarbons.** Page 5

■ **World Bank announces major new environmental protection initiatives.** Page 5

■ **Congress repeals 1978 law that prohibited large energy users from burning oil and natural gas in new boilers.** Page 6

■ **Chemical industry has mixed reactions to House trade bill, which would strengthen U.S. intellectual property laws but allow 60% tariff reductions.** Page 6

Cover: Superconductivity is demonstrated as pellet of superconducting ceramic floats above a magnet at Argonne National Laboratory. The magnet induces superconducting currents in the pellet, previously cooled to 77 K with liquid nitrogen. The currents create a countermagnetic force to levitate the pellet

Letters 2

Concentrates

Business 17

Government 25

Science/Technology 28

The Departments

ACS Focus 34

ACS News 35

Meetings 36

Newsprints 52

Business

Earnings of 30 largest U.S. chemical firms rose a composite 34% in first-quarter 1987, continuing string of rises. Page 20

Government

NSF chemistry advisory group endorses new postdoctoral fellowship program, discusses plans for science and technology centers. Page 26

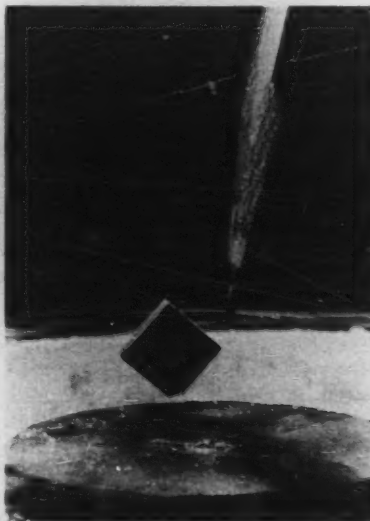
Technology

Catalytic tail-gas desulfurization process, now being commercialized by Mobil Oil, has low energy costs and no waste disposal problems. Page 29

Computer software program predicts degree of toxicity based on the structure of a chemical. Page 30

Books

Malcolm MacPherson and E. P. Dutton trace the early history of nuclear energy and the U.S.-German race for the atomic bomb. Page 31



News Focus

Recent discoveries of metal-oxide ceramics that are superconductors at temperatures near 100 K may lead to a revolution in electricity. Page 7

Chemical Earnings' String of Rises Continues in First Quarter

Profits of 30 largest U.S. chemical firms increased a composite 34%, but income of oil producers fell despite higher chemicals earnings

William J. Storck, C&EN New York

The string of earnings increases for the chemical industry continued in the first quarter of 1987. According to composite results for the 30 largest U.S. chemical companies, profits rose about 34% over the same period in 1986. Earnings also increased at most diversified companies that are producers of chemicals.

However, oil companies that produce chemicals were not so fortunate, as total earnings fell because of the weak oil economy. Nonetheless, their earnings from chemical operations improved over the year-earlier level.

Chemical companies are still reaping the benefits of the streamlining of their operations over the

past several years. These include the modernization of plants, realignment of corporate operations such as disposal of minimally profitable businesses, and, probably most important, the reduction of employment rolls and associated employment costs. This streamlining has lowered breakeven points at chemical companies and has provided them, in many cases, with earnings leverage sufficient to boost profits out of proportion to even a slight improvement in operations.

Fortunately the companies are getting slightly higher operating rates as demand increases with the improving economy. Only two major markets for chemicals—fertilizers and oil field chemicals—continue to slide. There are indications of some improvement even in these two sectors, as the farm economy begins to show signs of strengthening and as the price of oil increases enough to justify some domestic oil field activity.

Consequently, output of chemicals and allied products in the first quarter of 1987 improved almost 5% over the year-earlier level, accord-

ing to seasonally adjusted government data.

Although official labor department statistics show prices still below year-earlier levels, they are strengthening on a quarter-to-quarter basis. And, according to chemical company executives, they are strengthening for certain products. Pricing problems in a period of falling oil and gas prices is an old story for the chemical industry, as chemical customers demand passthrough of any cost break that the producers receive on raw materials. Now that the price of oil has increased, price increases seem to be easier to push through.

Also aiding demand in the first quarter was a steadily improving foreign trade picture. Export demand for U.S. chemicals has been growing while imports into the U.S. have been declining. However, this trend is not as strong as the chemical industry would like. And it is somewhat skewed by large imports of finished goods containing chemicals that are not reflected in the chemical trade figures.

As a result of the increased de-

Chemical industry leaders for the first quarter

Sales		
Rank 1987	\$ Millions	Rank 1986
1 Dow Chemical	\$3015.0	1
2 Monsanto	1866.0	2
3 Union Carbide	1681.0	3
4 American Cyanamid	1014.1	4
5 W. R. Grace	926.6	5
6 Hercules	664.3	7
7 National Distillers	656.7	10
8 Rohm & Haas	533.1	8
9 Air Products	527.1	9
10 B. F. Goodrich	485.6	6

Earnings*		
	\$ Millions	Rank 1986
Dow Chemical	\$246.0	1
Monsanto	138.0	2
Union Carbide	66.0	7
American Cyanamid	65.1	3
Rohm & Haas	57.4	6
Hercules	47.7	4
Ethyl	46.4	8
Air Products	41.1	5
National Distillers	28.9	12
International Flavors	27.6	10

Profitability		
	Earnings as % of sales	Rank 1986
International Flavors	15.4%	1
Ethyl	11.9	3
Betz Laboratories	11.0	2
Rohm & Haas	10.8	8
Locliffe	9.7	7
Nalco Chemical	8.6	4
Dow Chemical	8.2	11
Lubrizol	8.1	11
Air Products	7.8	4
Vista Chemical	7.4	13
Monsanto	7.4	10

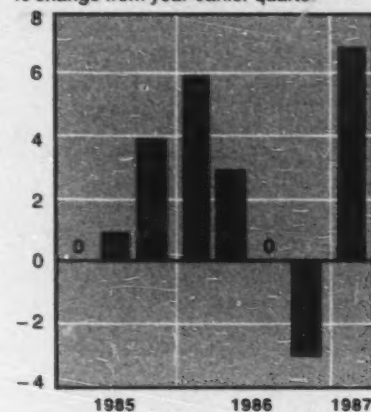
Note: For 30 chemical companies listed on page 22. * After taxes.

Chemical industry 1987 first-quarter results

- Sales climbed 7%
- Earnings jumped 34%
- Profit margins increased
- Production rose 4.7%
- Prices fell slightly

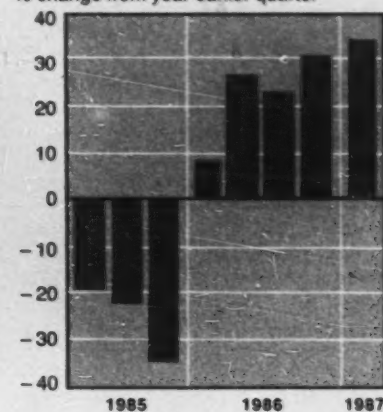
Sales

% change from year-earlier quarter



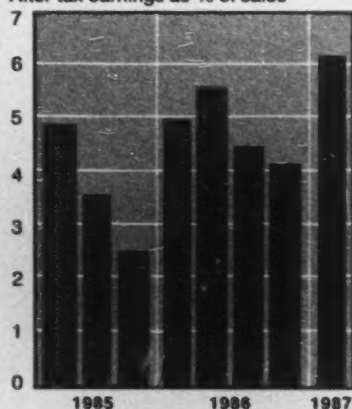
Earnings

% change from year-earlier quarter



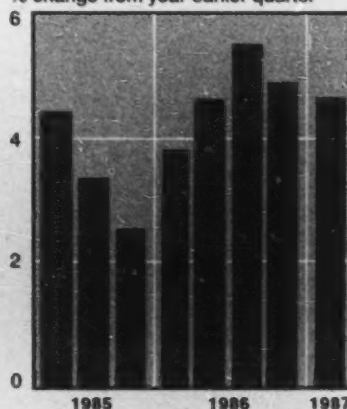
Profit margins

After-tax earnings as % of sales



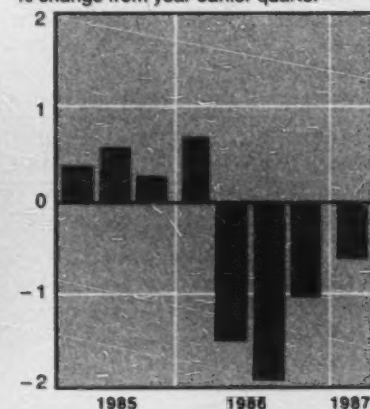
Production

% change from year-earlier quarter



Prices

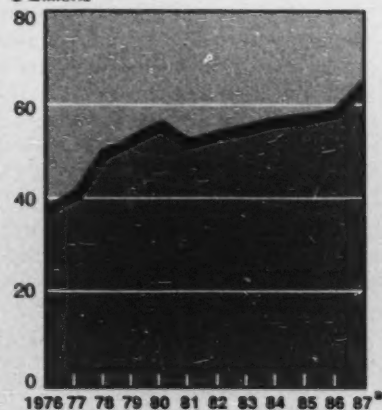
% change from year-earlier quarter



Sales in 1987 will climb about 10% and earnings will increase 25%, boosting profit margins to 5.7%

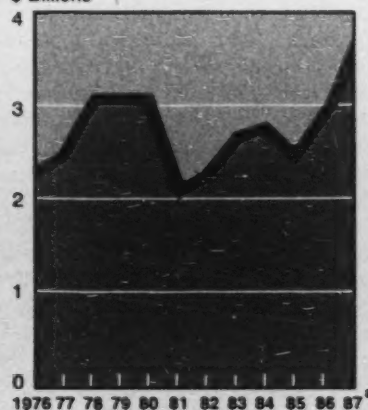
Annual sales

\$ Billions



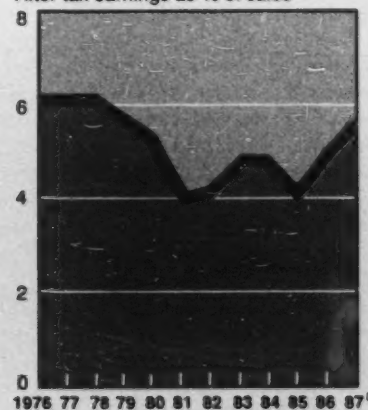
Annual earnings

\$ Billions



Annual profit margins

After-tax earnings as % of sales



Note: All sales, earnings, and profit-margin data are based on combined results of 30 companies listed on page 22. a C&EN estimates.

Earnings, profit margins increased substantially in first quarter

	FIRST-QUARTER 1987						12-MONTH RUNNING DATA			
	Sales	Earnings ^a	Change from 1986		Profit margin ^b		Change from 1986		Profit margin ^b	
	(\$ millions)		Sales	Earnings	1987	1986	Sales	Earnings	1987	1986
Air Products ^c	\$ 527.1	\$ 41.1	6%	5%	7.8%	7.8%	7%	-2%	7.1%	7.8%
American Cyanamid ^c	1,014.1	65.1	10	33	6.4	5.3	10	46	5.6	4.2
Aristech	208.7	13.6	7	84	6.5	3.8	na	na	na	na
Betz Laboratories	88.6	9.7	6	2	11.0	11.3	5	-3	10.2	11.0
Cabot ^c	331.2	19.4	-3	3	5.9	5.5	-11	-6	5.1	4.8
Chemed	91.2	4.3	11	24	4.7	4.2	5	-3	4.5	4.8
Crompton & Knowles	55.8	2.4	4	11	4.2	4.0	-2	8	3.8	3.5
Dow Chemical ^{c,d}	3,015.0	246.0	10	41	8.2	6.4	-1	560	7.0	1.1
Ethyl ^c	389.0	46.4	3	32	11.9	9.3	3	31	11.6	9.1
First Mississippi	71.3	2.3	9	3	3.3	3.4	-9	-60	1.7	3.8
Freeport-McMoRan	218.8	7.7	37	-16	3.5	5.7	0	-27	7.8	10.7
H. B. Fuller	137.4	3.6	15	31	2.7	2.3	17	38	3.6	3.1
B. F. Goodrich ^c	485.6	3.8	-33	def	0.8	def	-27	-319	1.7	-0.6
W. R. Grace ^c	926.6	11.7	10	75	1.3	0.8	-43	-82	0.5	1.7
Hercules ^c	664.3	47.7	3	5	7.2	7.0	2	45	7.9	5.5
International Flavors	179.0	27.6	21	25	15.4	14.9	23	23	14.0	14.0
International Minerals ^c	456.0	18.6	53	589	4.1	0.9	23	-223	-0.9	0.9
Loctite	89.7	8.7	34	81	9.7	7.2	25	27	9.3	9.1
Lubrizol	272.6	22.1	-1	26	8.1	6.4	-18	-1	7.7	6.3
Monsanto ^c	1,866.0	138.0	7	17	7.4	6.8	2	50	4.6	3.1
Nalco Chemical	191.6	16.5	7	18	8.6	7.8	8	-13	8.1	10.0
National Distillers ^c	656.7	28.9	39	64	4.4	3.7	-3	35	3.5	2.5
Olin ^c	467.7	21.5	4	-20	4.6	6.0	0	-3	3.0	3.1
Pennwalt	276.5	12.4	4	-14	4.5	5.2	7	191	4.5	1.7
Petrolite	63.9	4.0	-16	-31	6.3	7.7	-13	-26	5.8	6.9
Reichhold Chemicals	183.8	2.5	-12	96	1.4	0.6	-13	-209	1.2	-1.0
Rohm & Haas ^c	533.1	57.4	-1	50	10.8	7.1	1	34	9.1	6.8
Union Carbide ^c	1,681.0	66.0	6	74	3.9	2.4	-15	-13	2.5	2.4
Vista Chemical	151.8	11.2	1	25	7.4	6.0	na	na	na	na
Witco ^c	333.9	13.3	-3	-6	4.0	4.1	-6	8	4.8	4.2
Total 15 larger companies	\$13,347.3	\$824.7	7%	37%	6.2%	4.8%	-9%	18%	4.3%	3.3%
Smaller 15 companies	\$ 2,280.8	\$148.6	7%	19%	6.5%	5.9%	1%	9%	6.4%	6.0%
GRAND TOTAL ^d	\$15,628.1	\$973.3	7%	34%	6.2%	5.0%	-8%	16%	4.6%	3.7%

^a Earnings from continuing operations, excluding major nonrecurring and extraordinary items. ^b Earnings as a percentage of sales. ^c One of the 15 largest companies. ^d Averages for 12-month running data do not include Dow, where figures include a major nonrecurring item, and Aristech and Vista for which figures are not available. ^{def} = deficit. ^{na} = not available.

mand and slightly higher prices for some chemical products, earnings and profitability soared in the first quarter for major chemical companies. For the 30 major chemical companies surveyed by C&EN, composite earnings for the quarter amounted to \$973 million, up 34% on a sales boost of just 7% from the first quarter of 1986 to \$15.6 billion.

Profitability as a result moved up considerably. Profit margins (earnings as a percentage of sales) for the 30 companies averaged 6.2% in the first quarter, up from 5.0% in the year-earlier period.

On a quarter-to-quarter basis,

earnings for the 30 companies climbed 51% in the first quarter from a weak fourth-quarter 1986. Sales were up 3.3% on a quarterly basis. The first-quarter profit margin of 6.2% was a vast improvement from 4.2% in the fourth quarter of 1986.

As in the past few quarters, the larger, more diversified companies surveyed outperformed the smaller companies in terms of growth. The smaller firms, however, continued to win out in profitability. For the 15 larger firms surveyed by C&EN, earnings climbed an average of 37% to total \$825 million on a sales rise of 7% to \$13.3 billion. Earnings for

this group soared almost 76% on a sales increase of 7% from the fourth quarter of 1986. Profit margins for first-quarter 1987 for the 15 firms averaged 6.2%, compared with 4.8% in the first quarter of 1986 and just 3.7% in the fourth quarter of that year.

For the 15 smaller companies, first-quarter earnings increased a composite 19% from first-quarter 1986 to \$149 million, again on a 7% sales rise to \$2.28 billion. Compared with last year's fourth-quarter, sales were down about 12% and earnings fell 14%. Profit margins at the smaller companies averaged 6.5% in the first quarter of this year, compared

Ground rules for C&EN earnings analysis

C&EN's quarterly report on financial performance of the U.S. chemical industry contains data from the 30 largest U.S. basic chemical companies and from 34 oil and diversified companies, each with more than \$200 million in annual chemical sales.

To be included in the table of basic chemical producers, a company must have at least 50% of its sales in chemicals. That is why Du Pont, for example, is included in the table of diversified manufacturers.

In referring to chemical sales, C&EN means those chemicals whose molecular composition has been changed in the course of manufacture. Hence, chemical sales include those of traditional categories of basic petrochemicals and inorganics, organic intermediates and inorganic compounds, polymers such as plastics and fibers, agricultural chemicals, and specialty derivatives.

In listing earnings, the survey gives after-tax income for continuing operations before nonrecurring items and extraordinary charges. Foreign currency translations are included.

with 5.9% in the same period in 1986 and 6.6% in fourth-quarter 1986.

The restructurings, improved costs, and better volumes all are evident in company comments on the quarter's earnings. For Du Pont, the largest U.S. chemical producer, chairman Richard E. Heckert says that its increased chemical earnings reflected improved results for most businesses, notably fibers, white pigments, and specialty polymers. And, he points out, results benefited from improved worldwide demand and lower costs attributable to lower energy and feedstock prices, earlier restructurings, and aggressive efforts to improve productivity.

Chemicals carried the day at Du Pont in the first quarter, where after-tax operating income for chemical operations was 55% ahead of the comparable period in 1986. The company's oil earnings fell 64% from the same period last year.

For Dow Chemical, whose earn-

Profits up for most diversified firms, down for oil producers

	% chemical sales	FIRST-QUARTER 1987					
		Sales (\$ millions)	Earnings ^a	Change from 1986		Profit margin ^b	
				Sales	Earnings	1987	1986
OIL AND GAS COMPANIES							
American Petrofina	23%	\$ 539.5	\$ 19.8	7%	def	3.7%	def
Amoco	15	5,200.0	260.0	-12	-21%	5.0	5.6%
Ashland	20	1,600.0	-8.0	-11	def	def	2.3
Atlantic Richfield	33	3,744.0	245.0	-13	-18	6.5	7.0
Chevron	9	6,800.0	150.0	-23	-56	2.2	3.9
Exxon	8	19,435.0	1,044.0	-13	-46	5.4	8.7
Kerr-McGee	14	546.8	20.2	-24	-9	3.7	3.1
Mobil	4	12,700.0	252.0	-9	-43	2.0	3.2
Occidental Petroleum	13	4,157.0	70.0	14	-22	1.7	2.5
Phillips Petroleum	17	2,540.0	-32.0	-18	def	def	3.1
Shell Oil	20	4,500.0	108.0	-4	-61	2.4	5.9
Standard Oil	5	2,488.0	200.0	-14	-21	8.0	8.7
Sun Co.	3	2,230.0	38.0	-33	-74	1.7	4.4
Texaco	4	8,500.0	118.0	-11	-64	1.4	3.4
DIVERSIFIED MANUFACTURERS							
Allied-Signal	25	2,637.0	102.0	8	-41	3.9	7.0
Borden	33	1,428.5	44.0	26	20	3.1	3.2
Borg-Warner	31	878.0	39.0	5	11	4.4	4.2
Dexter	38	187.1	9.5	14	16	5.1	5.0
Du Pont	45	7,128.0	391.0	-1	-3	5.5	5.6
Eastman Kodak	22	2,655.2	178.0	13	266	6.7	2.1
Eli Lilly	19	1,059.0	205.2	7	19	19.4	17.5
Emhart	15	602.6	22.9	18	20	3.8	3.7
Englehard	29	538.0	13.5	2	18	2.5	2.2
FMC	51	724.3	25.3	-4	-2	3.5	3.4
GAF	48	191.1	20.6	9	37	10.8	8.5
Kaiser Aluminum	12	537.3	-29.3	98	def	def	6.1
Koppers	42	271.7	-3.0	6	def	def	def
Merck	9	1,111.1	201.3	21	28	18.1	17.1
3M	15	2,207.0	213.0	7	18	9.7	8.7
Morton Thiokol	37	519.8	36.2	0	0	7.0	7.0
PPG Industries	18	1,261.0	86.9	11	26	6.9	6.1
Pfizer	9	1,119.6	192.0	8	14	17.1	16.4
Tyler	40	256.1	1.0	11	16	0.4	0.4
Vulcan Materials	27	212.8	11.4	6	43	5.4	4.0

^a From continuing operations excluding nonrecurring and extraordinary items. ^b Earnings as a percentage of sales. def = deficit.

ings were up 41% from last year's first quarter, chairman Paul F. Orefice states, "Volume increases were reported for most products, and the pricing environment continued to improve in response to a better balance between supply and demand worldwide. In basic chemicals, volumes were up and prices were generally firm or trending upward."

Pricing also was important at Olin. In spite of a decline in earnings for the quarter, pretax earnings bene-

fited from improved pricing, according to chairman John M. Henske. He notes, "During the quarter, pricing trends for our products began to improve for the first time in several years and by year's end we expect our price index to be up."

Monsanto chairman Richard J. Mahoney says, "Volumes and prices for many chemical-based products were ahead of year-ago levels." However, he cautions, "the costs of certain raw materials have increased significantly in recent months,

Chemical earnings surge at oil companies

Although oil company earnings overall were suffering because of slumping oil prices, earnings from chemical operations certainly were not ailing.

For seven oil companies that also produce significant quantities of chemicals—chiefly petrochemicals—earnings from chemical operations in the first quarter rose 28% from 1986's first quarter to a composite \$498 million. That's somewhat lower than the increase in earnings for the 30 largest U.S. chemical firms. However, if Shell Oil, whose chemical earnings plummeted 44% in the first quarter, is omitted from the group, the increase becomes almost 45% over the previous year's quarter. Shell's earnings are not comparable with those of the other six companies, because it sold a large part of its chemical operations during 1986 and has not restated its chemical earnings to reflect the sale.

Exxon was the biggest gainer in the first quarter, with a 62% increase in

chemical earnings to \$186 million. Exxon says that strong demand boosted volumes both in the U.S. and abroad. However, a portion of the foreign increase came from nonrecurring tax credits.

For Atlantic Richfield, which registered a 43% increase in chemical earnings to \$83 million, the results were split. Arco Chemical, which produces intermediate chemicals and specialty products, says volumes and margins improved for its oxygenated products, resulting in after-tax earnings of \$61 million, a 135% increase over first-quarter 1986. However, for the company's Lyondell Petrochemical Co. unit, lower profits on refined products and petrochemicals resulted in a 31% decline in earnings to \$22 million for the quarter, including a nonrecurring charge.

Mobil, with a 34% rise in chemical profits to \$43 million, reported higher earnings and increased sales volume in both domestic petrochemical operations and U.S.- and European-oriented polypropylene film.

For Amoco, with a 22% rise in chemical earnings to \$85 million, it was the same story. The company says that sales volumes for chemical and polymer products increased as demand continued to grow, and earnings on polymer products were higher than the relatively weak levels of the previous year. Amoco says that results for most plastic products and specialty chemicals activities also improved.

\$ millions	1987	1986	% change
Amoco	\$ 85.0	\$ 72.0	22%
Atlantic Richfield	83.0	58.0	43
Chevron	50.0	33.0	52
Exxon	186.0	115.0	62
Mobil	43.0	32.0	34
Shell	40.0	72.0	-44
Texasco	8.0	8.0	33
TOTAL	\$498.0	\$388.0	28%

^a After-tax earnings.

squeezing some profit margins." Monsanto's earnings in the first quarter were up 17% over the same period last year.

Not all pricing news from the companies was good, however. PPG Industries chairman Vincent A. Sarni says that at that company, substantial chemicals volume improvements were offset somewhat by continued weak pricing.

Other companies, like Monsanto, have been confronted with rising raw material costs. For Reichhold Chemicals, whose earnings almost doubled from the same period last year, chairman C. Robert Powell

states that, though earnings showed improvement over last year's first quarter, the improvement is not so good as the one recorded by the firm in the second half of 1986. "This reflects the dramatic increase in raw material costs in the first quarter, particularly affecting our emulsion polymers business," he adds.

Plastics, and particularly polyvinyl chloride, seemed to have a good quarter. For instance, Vista Chemical's earnings increased 25%, and they were up primarily because of higher PVC profits, according to Vista president and chief executive officer John D. Burns. The improve-

ment came from higher product prices and lower-cost ethane feedstock.

At B. F. Goodrich, the PVC industry leader, chairman John D. Ong says that demand for PVC products is high and the company likely will report an improved level of operating income this year.

The agricultural chemicals market also began some strengthening in the first quarter. Earnings from crop chemicals increased 34% to \$165 million on a sales rise of 18% to \$382 million at Monsanto. "Monsanto Agricultural Co. recorded excellent results as Roundup herbicide continued to penetrate new markets around the world," Monsanto's Mahoney notes. "Lasso herbicide maintains satisfactory volumes, in spite of a highly competitive marketplace and anticipated reductions in corn acreage planted in the U.S."

International Minerals & Chemical chairman George Kennedy adds, "Cost performance continued to be outstanding and volume was as forecast. What really helped the quarter, though, was some slight improvement in fertilizer prices. The benefit to our bottom line demonstrated the earnings leverage in IMC's fertilizer business."

The good results in the first quarter have caused optimism about the balance of the year at many chemical companies. Olin's Henske says: "We expect operating income for the second quarter to be up significantly from last year and overall earnings to be comparable to this year's first quarter. The outlook for 1987 points to significant increases in Olin's operating income for the full year."

Monsanto's Mahoney predicts, "We expect 1987 to be another good year for Monsanto. Our strong businesses are remaining strong and our weaker businesses are improving their financial performance through strict cost control. Given a stable economic environment, we anticipate significant progress this year toward our stated long-term goals."

And Dow's Orefice says, "The momentum our business built in the first quarter will continue in the second quarter and should make for a successful year." □

MAY 18, 1987

CHEMICAL & ENGINEERING

NEWS

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Rubber Processing Chemicals

Producers face overcapacity with few growth prospects Page 29

News of the Week

■ **Single-crystal thin film is key to measuring dramatically higher current-carrying capacity of high-temperature superconductors.** Page 4

■ **Two Italian firms, Montedison and EniChem, are continuing to discuss a possible merger, but the outcome remains unclear.** Page 5

■ **In Bhopal liability case, attorneys representing both India and Union Carbide tighten up strategies during discovery process.** Page 5

■ **Chemical engineering professor Harry Drickamer wins Welch award in recognition of his discovery of pressure tuning spectroscopy at very high temperatures.** Page 5

■ **Niagara Falls' mists may contain several toxic chemicals from the polluted river, according to Canadian groups probing the issue.** Page 6

Business

ICI Americas chairman **Harry Corless**, 1987 Palladium medalist, reflects on company's rapid growth in U.S.; market survey indicates slow worldwide growth for ethylene oxide and ethylene glycol; petrochemical industry outlook remains good as high operating rates continue. Page 13

Government

Academic labs face compliance with right-to-know regulations dealing with possession or spills of hazardous chemicals. Page 19

Technology

Natural gas producers aim at bigger share of electric power generation market; two new enzymes exhibit high thermostability, produce cyclodextrins from starch. Page 22

Science

Secret of an arctic moth that tolerates winter temperatures of -70°C or lower may be its production of glycerol. Page 28

Books

The history of U.S. research in organic chemistry is traced in a series of comprehensive essays. Page 50

ACS News

Committee on Professional Training reports on 1986 bachelor, master, and Ph.D. graduates of ACS-approved schools; Indiana continues to be top producer of B.S. chemists. Page 59

Cover: Photo courtesy of Goodyear

Letters	2
Concentrates	
Business	7
Government	18
Science/Technology	21
The Departments	
New Products	54
ACS Comment	58
Meetings	68
Newsclips	92



Product Report

The rubber-processing chemicals industry, which has suffered reduced markets in the past decade, faces modest growth at best for the rest of the 1980s. Page 29

Rubber-Processing Chemicals

Bruce F. Greek, C&EN Houston

The rubber-processing chemicals industry, oversupplied for a number of years, faces a growth outlook that's modest at best for the rest of this decade. By the early 1990s, production of the large number of chemicals required to fabricate rubber products likely will remain below output of the late 1970s. Nonetheless, the importance of this industry is difficult to overlook, considering the heavy dependence on it by transportation and many other types of human-oriented activity.

The commercially significant rubber-processing chemicals comprise about 125 different organic chemicals produced by about 20 large and small companies. Rubber-processing chemicals are only part of the large quantities of materials used to fabricate a host of rubber products. Other materials include inorganic chemicals, such as pigments and fillers; minerals, such as sulfur; metals; steel wire used in tire beads; oils; fibers of both organic and inorganic compounds; and other reinforcing materials, such as carbon black.

Rubber-processing chemicals differ from many other materials used in rubber goods manufacturing and might rightly be called the prima donnas of the business. They gen-

erally cost from two to a hundred times as much as the other materials. Relative to the quantities of rubber and other materials used in a fabricated product, they are consumed in tiny amounts but have a major and critical impact on the final product. Their chemical structures usually are complex, and consequently their manufacture often is difficult, requiring expensive equipment, batch operations, and a high degree of attention to plant operation and to quality control.

Output of rubber-processing chemicals in 1987 will about equal 1986 production of 260 million to 280 million lb. That level will be only slightly higher than 1985 production of 260.1 million lb, according to the U.S. International Trade Commission. A 1987 production level of only 265 million lb would be 33% or more less than production 10

years ago, when the total was 402 million lb.

The value of rubber-processing chemicals produced in the U.S. this year likely will total \$375 million to \$400 million, based on estimates of production. However, about a third of production reported to ITC is captive production. So the other two thirds will bring less than \$300 million to producers as outside sales.

Sales values are increased, however, by the value of rubber-processing chemicals imported into the U.S. Data on imports, considered incomplete and inaccurate by some industry sources, likely will show that imports will be about 10% of U.S. production this year, which will add about \$40 million to the total sales volume. Sales figures include exports that are forecast to hold at about an eighth of production, or about 40 million lb.



Monsanto recently added to its rubber chemicals plant located east of St. Louis

Foreign trade in rubber-processing chemicals is not constant. Many factors influence it. The strength of the dollar before 1987 is an example. It encouraged foreign producers to sell into the U.S. at competitive prices, and that has caused imports to rise in recent years. Additional capacity to make rubber-processing chemicals in developing countries and Eastern Europe is reducing exports from Western European producers and causing a continued interest in exporting to the U.S., despite continued decline in the value of the dollar.

Higher imports of tires, both those on imported cars and those for replacement sales, have resulted in drastic reductions in U.S. tire production. Consequently, U.S. consumption of rubber by manufacturers has declined. That decline has been exacerbated by the capture of some of the rubber mechanical goods markets by similar products made from plastics. The eventual result, naturally, has been a decline in production and sales of rubber-processing chemicals.

Other significant developments in the industry have been in the chemicals themselves. Producers continue to improve the usefulness of

those chemicals by modifying them through changes in structure. They are discovering new compounds that provide desired activities with fewer unwanted side effects and that have reaction rates that reduce the quantities required, saving fabricators money.

But the decline in U.S. tire production, in terms of units produced, doesn't tell the whole story of the decline in rubber consumption. Last year, tire production was down to 190 million units, or 3.6% less than 1985. More troubling, though, is that 1986 output was down 42 million units, or about 18%, from 1977 production of 232 million.

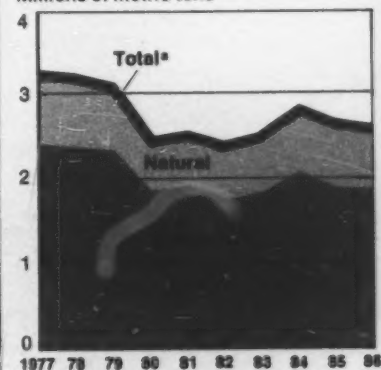
The fewer tires that were produced by U.S. manufacturers consisted of the much improved radially tires that give much longer life and the smaller tires needed by smaller, lighter cars. Radial tires for cars, trucks, and buses accounted for 79% of the 190 million tires produced in 1986, up from 56% of the 182 million tires produced in 1981. Those two shifts in tire production—in number of tires and type of tires—combine to reduce consumption of rubber and rubber-processing chemicals.

Shipments of tires in the U.S. are up somewhat from a decade ago, which indicates the impact to producers of imported tires. In 1986, shipments increased slightly to a new high of 243 million units, up 7% from 1977 shipments of 227 million units. (The production of 232 million units in 1977 suggests that imports had little effect that year on tire output and rubber and rubber processing chemicals consumption.)

Rubber consumption by manufacturers has declined steadily in the U.S. during the past 10 years, from more than 3.2 million metric tons in 1977 to just over 2.6 million metric tons last year. Consumption of natural rubber, however, has remained nearly constant, at 750,000 metric tons last year, as it did the two preceding years. The decline has occurred in synthetic rubber, with the demand in 1986 at 1.87 million metric tons, down nearly a quarter from the 1977 demand of 2.46 million metric tons. Much of the reduction in consumption has

U.S. elastomer demand remains below 1977 level

Millions of metric tons



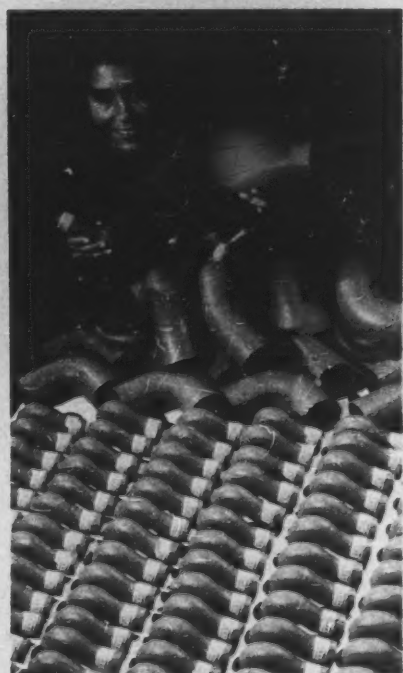
a Excludes reclaimed. b All types.

Source: Rubber Manufacturers Association

been in styrene-butadiene rubber (SBR), polyisoprene, and nitrile, with new specialty rubbers on the market partially offsetting the decline.

Natural rubbers' share of total rubber use has increased slowly from less than 25% in 1977 to more than 28% last year, owing mainly to the decline in consumption of synthetic rubber. Now that crude oil prices are holding at about two thirds the price prevailing in the first half of the decade, the gain in natural rubber's share of consumption may slow this year. Because negligible amounts of hydrocarbons and energy are used in producing natural rubber, its cost has increased more slowly than that of synthetic rubbers. The shift to radial tires has added to demand for natural rubber because of its lower heat buildup during flexing.

Although declining industrial-rubber consumption has had a major impact on demand for rubber-processing chemicals, the shift toward radial tires and an increased use of natural rubber in tires have affected demand, too. For example, radial tires, with their longer life, require more antidegradants—antioxidants and antiozonants—to protect the rubber over longer exposure to weather. Natural rubber requires that more processing chemicals be used to lower its viscosity during fabrication, but much of that requirement for chemicals is offset by a natural antioxidant that is a protective during fabrication, there-



Truck radiator hoses use variety of rubber-processing chemicals

Product Report

by reducing demand for synthetic antioxidants during fabrication.

In the manufacture and marketing of rubber-processing chemicals, producers have found themselves on a treadmill to provide improved service while at the same time to operate profitably. Not all producers have been able to do that. As a result, a considerable number of producers have left the rubber-processing chemicals business. In little more than a decade, the number of companies reporting production and sales of rubber-processing chemicals to the International Trade Commission has dropped about a third. The number of companies producing those chemicals is expected to decline further in 1987, on the heels of rumors that at least one small producer intends to stop its operations.

Because of the sharp competition, companies remaining as the suppliers of rubber-processing chemicals have, over the past 10 years, been

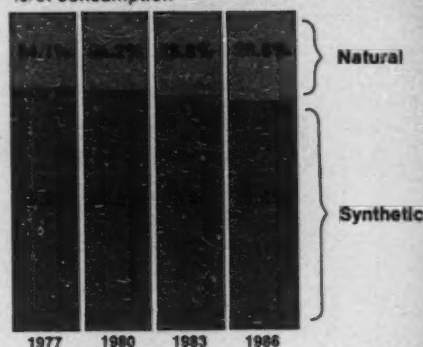
forced to make many changes in both their production and marketing operations. Companies have undertaken complex arrangements to determine the most profitable ways to run their business. For example, a few producers of rubber-processing chemicals have ended their marketing efforts for some or all of their line. Some continue, however, to manufacture for companies now marketing the chemicals.

Some of the major tire companies have cut back on the number of different rubber-processing chemicals they sell, besides the ones they sell and consume captively. Distributors and importers have added rubber-processing chemicals to their line of marketed products, which adds to the total marketing effort.

In other cases, a chemical may be made by a single producer and sold to only a handful of specialty fabricators in a volume too small to gain much notice in the total of rubber-processing chemicals. Knowledge-

Natural rubber slowly gains in share of U.S. elastomer use

% of consumption*

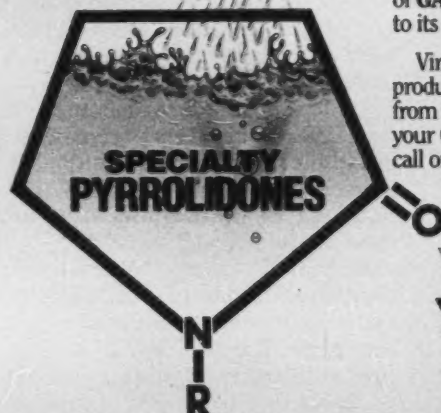


* Excludes reclaimed. Source: C&EN estimates

able people in this industry admit they still can't fully grasp all of the myriad marketing arrangements.

Despite changes to product lines and changes in the participants, the rubber-processing chemicals business is falling behind other busi-

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Product Report

Many compounds used in rubber processing

Of thousands tested, more than 200 organic chemicals and about 20 inorganic chemicals have been found to be useful in fabricating various kinds of elastomers into a host of consumer and industrial products. Before processing, raw rubber has few commercial applications. Compounding rubbers with various chemicals and subjecting the fabricated forms to heat and pressure converts them into useful items such as tires, hoses, and gaskets.

The organic chemicals used in rubber processing and that are included in this report often are complex molecules containing atoms other than carbon, hydrogen, and oxygen. Some of the compounds have been known for more than 100 years to be useful in rubber processing. It is not completely clear how some of the compounds provide the desired properties in the final fabricated rubber product—only that they are essential in providing those properties.

On the average, between 4.5 and 5.0 lb of rubber-processing chemicals are used per 100 lb of rubber during fabrication. Much higher quantities of processing chemicals will go into some rubber products because of the severe conditions to which the product will be subjected. The variety of chemicals used in a formulation, therefore, depends on the product service demands.

nesses in profitability, as it continues to be buffeted by overcapacity and rising imports. Prospects for growth in production are very limited. Several of the companies, nevertheless, have maintained large research and development operations that continue to add new products to their line. Many producers are modernizing plants and improving quality control during manufacture and handling of the chemicals, to cut their manufacturing costs.

Monsanto, for example, is completing additions to a rubber-processing chemicals plant located just east of St. Louis. This \$18 million unit will not increase capacity but is expected to trim costs of production, says Roger W. Spiller, direc-

Rubber-processing chemicals function in many ways. Antidegradants—antioxidants and antiozonants—are designed to protect rubber polymers both during and after processing. Accelerators speed the crosslinking reaction of polymer with sulfur in the vulcanization process. Activators (sometimes called secondary accelerators) may be used to potentiate accelerators. Other compounds, called retarders, delay vulcanization; certain sulfur donors and peroxides aid vulcanization; and peptizers reduce viscosity.

Some of the organic compounds used by the rubber industry and not covered in this report are peroxides, fatty acids, and sulfur compounds that initiate and regulate polymerization of rubbers. A variety of hydrocarbon oils used to extend and soften polymers also are not covered.

Among other substances not covered in this report are carbon black (used widely as a reinforcement), elemental sulfur (used as a primary vulcanization agent), and various inorganic oxides (used as activators in vulcanization). Numerous carbonates, silica, clays, and pigments used as fillers, reinforcements, and colorants are not covered. Those materials are used in large quantities in rubber fabrication. For example, most tires contain between 1.0 and 1.5 times as much carbon black, oils, and fillers as elastomer.

tor, commercial, Monsanto's rubber chemicals division. The company is continuing with its R&D programs in rubber-processing chemicals. One of its latest new products is in the Santoguard line—a scorch (premature curing) delay additive. The company's product line includes antidegradants, accelerators, and vulcanizing agents.

Goodyear continues to put emphasis on rubber-processing chemicals in the antidegradant area. Goodyear, a major captive consumer of these chemicals, also has moved into stabilizers for rubber polymers. A recent development in that line is Wingstay K, a proprietary complex mixture for such rubbers as SBR and nitrile, says Roger O. Gilruth, mar-

ket manager of Goodyear's rubber chemicals division.

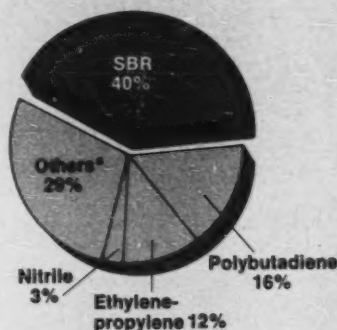
Mobay offers a broad line of rubber-processing chemicals, many of which are manufactured by its West German parent, Bayer, and imported into the U.S. The company began producing some antiozonants in the U.S. early in the 1980s with startup of a plant near Charleston, W.Va. A peptizing agent and a bonding system for various substrates are other new products Mobay makes in the U.S.

Producers and marketers of rubber-processing chemicals generally all operate in a similar way. Some, such as Goodrich, sell chemicals through R. T. Vanderbilt, a manufacturer, but best known as a distributor. Pennwalt, a smaller producer of rubber-processing chemicals, is popular for its line of accelerators. Uniroyal Chemical, once a part of Uniroyal, a major tire manufacturer, makes and sells a wide variety of antidegradants and miscellaneous rubber-processing chemicals. Witco's line covers various antidegradants, accelerators, and smaller-volume products such as mold-release agents.

A large number of other companies produce and market rubber-processing chemicals. About half a dozen of them act as distributors, often buying in bulk and repackaging under their own tradenames. Other companies, including some very large ones, such as Du Pont, Ethyl, Eastman Chemical, and W. R. Grace, make antioxidants that have application to a variety of products, including rubber. These companies often do not consider themselves part of the rubber-processing chemicals industry but, rather, a part of the larger specialty organic chemicals industry.

The major U.S. producers of rubber-processing chemicals also have plants in other parts of the world, notably in Western Europe. Those plants are used in a variety of ways to meet market demands throughout the world, while keeping as their objective the best combination of service and profitability. Some producers, for example, use their foreign plants to supplement capacity in the U.S., if their domestic capacity is insufficient to meet sales

SBP still largest-volume U.S.-made synthetic rubber



Total 1986 production = 1.99 million metric tons

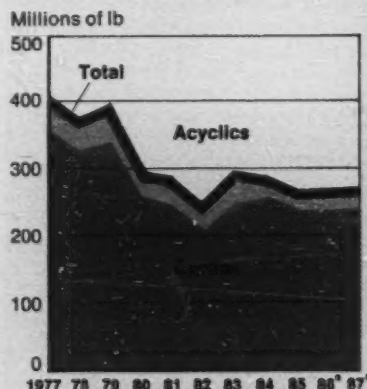
* Butyl, polyisoprene, polychloroprene (neoprene), silicone, and miscellaneous synthetic elastomers. Source: Rubber Manufacturers Association

requirements. The foreign plants also are used to make chemicals that are in demand in the U.S. but for which there are no units in the U.S. to make them. Conversely, U.S. capacity is used to supply markets in other parts of the world that cannot be met by production in foreign plants.

Many rubber-processing chemicals are reported to the International Trade Commission as having a single producer or vendor. In 1985, only one chemical was reported as having five sources. Two others had only four sources. Nine chemicals had three sources. Nearly 100 were reported by a single company.

Analysis of the actual consump-

Rubber chemical output below earlier levels



* C&EN estimates. Source: U.S. International Trade Commission

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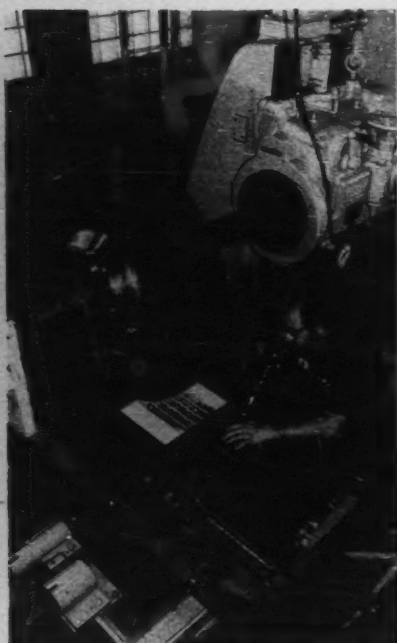
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Although output is down, tires still consume large quantities of chemicals

tion of the wide variety of these chemicals is difficult. There is considerable overlapping in their uses in rubber fabrication, as well as in other industries such as plastics, in which the same properties are desired as in rubber.

The wide variety of rubber-processing chemicals, however, can be classified, either by their functional activity or by their structural type. Two functional classes—antidegradants and accelerators—account for more than 90% of estimated U.S. consumption of those chemicals,

which in 1987 will total about 225 million lb. Antidegradants will account for about 120 million lb of that total and accelerators about 80 million lb. The remaining functional classes are vulcanizing agents, peptizers, retarders, blowing agents, and some miscellaneous chemicals. None of those functional classes of chemicals will grow very fast between now and 1990; some will have little or no growth and others may have 1 to 2% growth.

Of the 120 million lb of antidegradants that will be consumed in fabricating rubber products in the U.S. this year, about 60 million lb will consist of a variety of phenylenediamines. Another 16 million to 18 million lb will be phosphites. Various phenolic compounds will account for a slightly smaller amount. Quinolines use will amount to more than 12 million lb. Diphenylamines and others will total 15 million to 18 million lb.

Of the 80 million lb or so of accelerators (catalysts that aid the vulcanization process) used this year, nearly half will be sulfenamides. Other important accelerator compounds include benzothiazoles (16 million to 18 million lb), dithiocarbamates (less than 4 million lb), and thiurams (about 3 million lb). A large number of other compounds, many containing nitrogen, and blends of accelerator chemicals will total about 15 million lb.

Antioxidants, a major type of antidegradant, have a long history. They were first sought more than

Sales value, average prices of rubber-processing chemicals changed little during 1980s

	Cyclins		Arylates	
	Value of sales (\$ millions)	Average selling price (\$ per lb)	Value of sales (\$ millions)	Average selling price (\$ per lb)
1977	\$248.7	\$1.23	\$28.0	\$0.81
1978	258.3	1.29	28.8	1.03
1979	316.2	1.35	28.9	0.83
1980	269.9	1.61	28.1	1.00
1981	270.9	1.72	27.4	1.14
1982	240.7	1.79	22.9	1.21
1983	270.2	1.72	33.1	0.82
1984	259.6	1.69	25.8	1.16
1985	280.7	1.61	22.2	1.14
1986*	275	1.56	21	1.10

Note: Merchant sales quantities are well below reported production because of large captive demand, a C&EN estimate. Source: U.S. International Trade Commission

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May 18, 1987 C&EN 39

100 years ago, when fabricated rubber products were short-lived. Loss of flexibility (and subsequent cracking) and increased stickiness that caused undesirable adherence to surfaces (such as skin) were serious problems. Prior to 1910, pitch, creosote, and naphthalene from coking coal were among the more sophisticated materials used to protect rubber against deterioration.

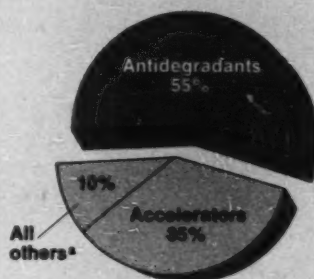
In subsequent years, these problems were partially alleviated by the use of organic chemicals purified from coal tar or derivatives synthesized from those organic chemicals. Useful compounds included aniline, various cresols, hydroquinone, phenol, and various simple amine and hydroxy derivatives of these compounds.

That range of derivatives laid groundwork for the development and testing of other more sophisticated derivatives, especially secondary aromatic amines. After World War II, when the use of synthetic

rubber in many new ways increased rapidly, a need was created for nondiscoloring antioxidants. The oxygenated compounds had held promise, but they also presented difficulties. To meet the need for such antioxidants, chemists made more complex phenol derivatives that were much more effective.

Antioxidants and antiozonants are used to resist the formation of peroxides at points along a rubber polymer chain. The formation results from a hydrogen atom being knocked off by energy (such as heat or light), according to Goodyear. The loss of hydrogen creates a radical that reacts with oxygen to form the peroxide. Subsequently, the newly formed peroxide can remove another hydrogen atom from the same or another polymer chain, which then produces another radical and a hydroperoxide. If two hydroperoxides react, a rubber alkoxy radical and another rubber peroxide form. Both of the radicals then

Antidegradants dominate rubber-processing chemicals



Total 1987 production = 265 million lb

* Vulcanizing agents, peptizers, retarders, and blowing agents.

remove hydrogen from polymer chains and the polymer destruction accelerates.

The net effect obtained from the process varies, depending on the kind of rubber polymer involved. Natural or polyisoprene rubbers soften as the result of chain-breaking and depolymerization. SBR and specialized rubbers (such as the urethanes, fluorinated elastomers, acrylics, and some silicone elastomers) harden because of cross polymerization of chains.

Chemical methods to minimize degradation involve a reaction of the chemicals with the peroxides that form when a hydrogen atom is removed from the rubber polymer chain. In one method, a hydrogen from the antioxidant, reacting with the peroxide, leaves a radical from the antioxidant. The radical then reacts with another peroxide, prevents the peroxide from removing a hydrogen from the polymer chain and from continuing the degradation process. Another method involves using antioxidants that react with the hydroperoxides.

The most common antioxidants that react with the peroxides formed by removal of hydrogen atoms are phenols, phosphites, and certain alkyl and aromatic amines, according to Goodyear. Numerous other compounds have some value as antioxidants, but they also have drawbacks that limit usefulness in conventional vulcanization systems.

The phenols (including bisphenols) have relatively large substituent groups on them and are generally known as hindered phenols.

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Product Report

The substituent groups may include styrene, alkyls of varying complexity, and combinations of these. The most widely used antioxidant of this group probably is the very active 2,6-di-*tert*-butyl-*p*-cresol.

The bisphenol antioxidants are similar in substituent structure to the phenols. They can be joined together at varying points on the ring as is desired. A sulfur atom sometimes is contained in the bridge structure and forms a compound that is quite active but causes some staining of the final product. The increased size of the molecule reduces its volatility, a property important to retention of the antioxidant for giving longer protection.

Other phenolic antioxidants are polyphenols and hydroquinone derivatives. The polyphenols have properties generally similar to bisphenols. The hydroquinones, with two hydroxyl groups on the ring, have properties that make them useful as stabilizers. They are often used in compounds containing polymers that otherwise would continue to polymerize during processing and storage. Many mixtures and blends of the phenolic antioxidants are commercially available for use in special circumstances.

A large number of alkyl and aromatic amines are used as antioxidants because of development of what has been called the first effective long-term antioxidant, phenyl- β -naphthylamine. As a class, the alkyl/aryl amines show wide varia-

tions in their resistance to direct oxidation. That factor is important to long-lasting protection for the rubber. This class of compounds is important among antidegradants for rubber and other materials such as plastics, because of their susceptibility to oxidation, which allows them to be oxygen scavengers.

Over the years, the types of amines used as antidegradants have shifted, as one or another compound has tested more favorably for a given fabricated rubber product. An example: Very few naphthylamines are used now.

The largest-volume amine antidegradants now sold are the *p*-phenylenediamine derivatives. This year about 60 million lb likely will be sold. The volatility, resistance to direct oxidation, and other properties of these compounds vary widely, making their selection difficult for rubber fabricators. At the same time, the various kinds and sizes of substituent groups allow broad adjustments to properties of a finished product. The *p*-phenylenediamines have either high or low reactivity as antiozonants in addition to being powerful antioxidants. They can stain modestly or heavily, and they can resist side-reactions with oxygen quite well or are rapidly deactivated. The *p*-phenylenediamines with both alkyl and aryl substituent groups frequently are blended with other types to modify either the physical form or the performance characteristics.



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Product Report

The quinolines constitute the second largest group of antidegradants. Relatively few derivatives of quinoline are of commercial importance, but some are sold in significant quantities. Polymerized 2,2,4-trimethyl-1,2-dihydroquinoline probably has the largest use where good aging and heat resistance are desired, even if some discoloration occurs.

Other commercially important amine antidegradants are the diphenylamines and various aldehyde-amine products. Diphenylamine can be combined with various alkyl and aromatic groups to make useful antioxidants. Both of those groups of derivatives have commercial significance. The alkylated derivatives are more volatile than are the aromatic ones. A styrenic derivative supplied by Goodyear may be substituted for phenolic antioxidants in compounds containing carbon black, which partially absorbs phenolic antioxidants.

The volume of various phosphites used as antioxidants will about equal or possibly surpass the volume of phenolics consumed this year. Both alkyl and aryl derivatives can be made. However, the majority of commercially important phosphite antioxidants are aryl-substituted. Some forms of phosphites having a small polymer (such as polypropylene glycol) between phosphorus atoms have been found to partially overcome a shortcoming, hydrolysis, of the most widely used form, tris-nonylphenol phosphite. All

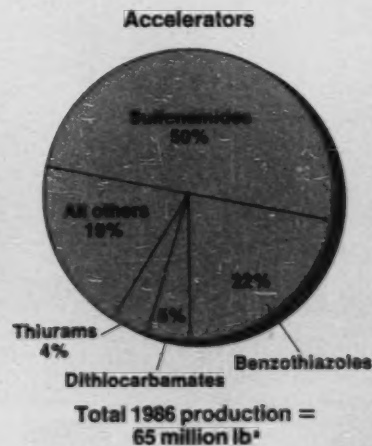
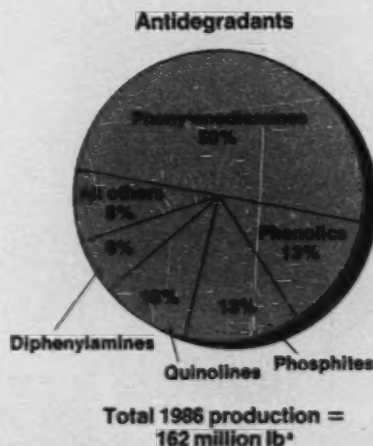


Engine builder adjusts tension on premium drive belt for race car engine

common phosphites are destroyed during vulcanization. Blends of phosphites and phenolic antioxidants frequently are used in rubber compounds.

Many of the antioxidants also are effective antiozonants, but the most important antiozonants are the various *p*-phenylenediamines. Dialkyl-, diaryl-, and alkylaryl-*p*-phenylenediamines are produced with each group having somewhat different

Antidegradants, accelerators comprise several chemicals



* C&EN estimate.

properties. Other antiozonants used in rubber processing include derivatives of urea, thiourea, and certain metal dithiocarbamates, although the volumes consumed of any of those are small compared with the *p*-phenylenediamines.

Using organic chemicals as antiozonants isn't the only way to protect rubber from ozone. If conditions do not involve flexing of the rubber, wax can be added to the compound. The wax moves to the surface and forms a film that is a barrier to ozone. When the film is broken by flexing, however, ozone will attack at the break with stress concentrated at the break, harming the rubber more than it possibly would otherwise.

Highly unsaturated rubbers, such as SBR, polybutadiene, and polyisoprene, are attacked more heavily by ozone than are highly saturated rubbers such as terpolymers of ethylene, propylene, and diene monomers (EPDM). In some rubber compounds, addition of EPDM to natural rubber or SBR will increase resistance to ozone with minimal loss of desired properties.

Before most antidegradants begin their work of protecting fabricated rubber products, the second largest group of rubber-processing chemicals comes into play. That group, the accelerators, catalyzes the vulcanization (or curing) process by aiding the crosslinking of rubber polymer chains with sulfur. After the crosslinking process, the product is elastic. The most important result from the development and use of accelerators is the vastly increased efficiency in rubber processing and fabrication. Use of sulfur alone to vulcanize rubber requires long reaction times. By vulcanizing in relatively short times, processors can add to the rubber compounds materials that provide desired properties but that would be completely destroyed during long curing times.

The first accelerators (although not recognized as catalysts) were metal oxides. The first organic accelerator was aniline, which was first used for that purpose early in the 20th century. Aniline is no longer used because of its toxicity and technical difficulties, but some of its derivatives are still used. During

the past 75 years, several thousand organic chemicals have been tested as rubber vulcanization accelerators, but less than 100 have found commercial use. Two classes of compounds—sulfenamides and benzothiazoles—account for more than two thirds of consumption.

Despite intensive research on the vulcanization process, the exact mechanism by which accelerators work remains uncertain. Most chemists agree that the accelerator, which contains sulfur atoms, attacks the elemental sulfur to form a polysulfide adduct. The adduct then becomes attached to the polymer chain with the accelerator opposite the chain, and a crosslink results through the polysulfide groups. Up to a point, a low level of sulfur in the crosslinkage improves stability of the rubber and its elasticity.

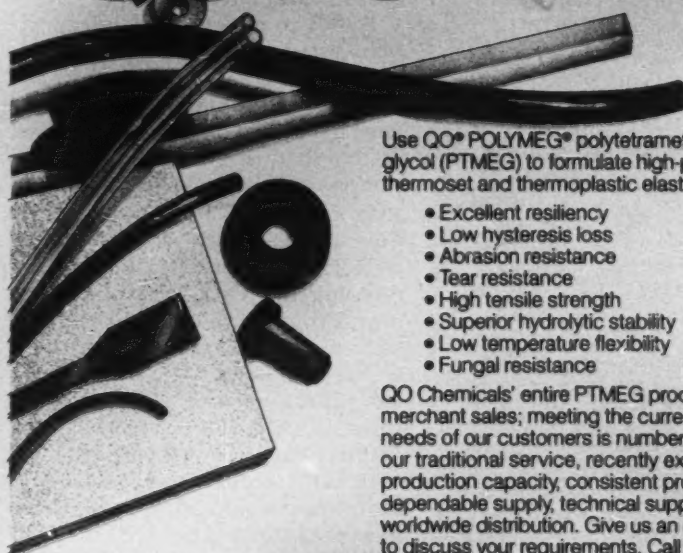
The discovery of 2-mercaptobenzothiazole more than 60 years ago as an efficient vulcanization accelerator brought about the various de-



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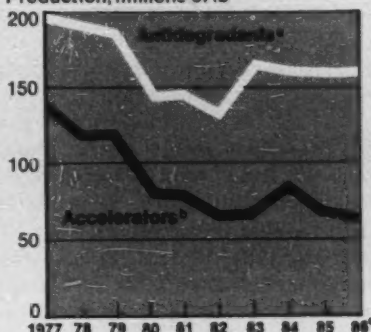
layed-action accelerators used today for high output rates of rubber products. Derivatives of the compound remain the widely used sulfenamides. Three sulfenamide derivatives are estimated to account for about 90% of the total accelerators used in the U.S. annually. They go largely into tires. Tire makers like the products because they have long scorch delays and provide good cure rates. The properties can be widely varied, however, according to selection of the amine used, so that the scorch delay is increased by more hindrance in the molecular structure, or less basic amines such as morpholine are used.

Other accelerators with significant demand include various dithiocarbamates and their derivatives. These reactive compounds are used as intermediates in making other chemicals, such as pesticides, and also are used in other processing, which makes accurate estimates of consumption in rubber fabrication difficult. The derivative list is large because of simplicity of formation. Very specialized uses take tiny quantities of some of these derivatives in a host of nontire rubber products.

From the dithiocarbamates, or sodium salts, comes another group of compounds—the thiurams. Many of

Cyclic antidegradants and accelerators still down

Production, millions of lb



a Antioxidants, antiozonants, and stabilizers.
b Accelerators, activators, and vulcanizing agents.
c C&EN estimate.
Source: U.S. International Trade Commission

those compounds provide the high cure rates of the dithiocarbamates. They sometimes are used as activators to increase cure rates with other, less reactive accelerators.

Other classes of compounds have some use as accelerators, but more often they are activators for other accelerators. Guanidines and products from reactions of certain aldehydes and amines to give undefined structures are examples. Those products go mostly into specialty cures, and the amount consumed this year could total about 5 million lb.

To obtain the efficient vulcanization systems that fabricators desire, a poorly defined group of chemicals, known as vulcanizing agents, have developed over the years. Generally, they are considered to be compounds that can donate a sulfur atom during vulcanization. Some of the compounds are accelerators as well. In a stricter definition, a vulcanizing agent must be a sulfur donor. A compound that is an organic sulfur donor might be used and, frequently, will produce an accelerator group as well. Thiuram sulfides are examples of active agents. Because the thiuram sulfides provide little scorch delay, some thiomorpholines and morpholinethio-benzothiazoles are used. If a delayed-action accelerator is combined with a thiomorpholine, more scorch delay will be obtained.

About 75 years after sulfur was found to be the key to rubber vulcanization, a different but similar

technology was discovered—peroxide cures. It wasn't until sometime after World War II that peroxide cures with rates useful in volume production of rubber products came into wide use. The process by which classes of compounds, such as dialkyl peroxides, cure rubber begins when free radicals that result from homolytic decomposition of the peroxide produce alkoxy radicals. These radicals remove a hydrogen atom from a polymer chain, to give an alkyl radical on the polymer chain. The radicals on polymer chains join to form crosslinkages.

The carbon-to-carbon bonds in these kinds of crosslinks have higher bond energies than do the sulfur-sulfur and sulfur-carbon bonds of vulcanizations that involve sulfur. Consequently, the products are more thermally stable than sulfur-cured vulcanizates. Peroxide cures generally are more uniform than sulfur cures and result in fabricated products with properties associated with stable crosslinks; for example, heat resistance and low compression set.

Peroxide cures have the disadvantage of causing different effects on different rubber polymers. There is also the need for the peroxide to decompose as completely as possible before the polymer mixture is exposed to oxygen. A third disadvantage is that peroxides are liable to react with other chemicals, such as antidegradants, added to the compound. Rubber polymers with high amounts of hydrogen on tertiary carbon atoms, such as butyl rubber, are less suitable for peroxide cures because radicals on chains are liable to cause the chains to break when crosslinking occurs. The antiozonants of the *p*-phenylenediamine group especially limit peroxide cures, because they are good traps for radicals.

The volume of alkyl peroxides used in rubber compounding is small at about 1.5 million lb. A big share of that volume is dicumyl peroxide. A variety of additives are used in small volume to improve peroxide cures, many of which have combination structures of olefins and functional groups.

Vulcanization retarders are another group of rubber-processing chemicals sold in relatively small vol-



Conveyor belts comprise large part of nontire rubber market



Specially designed hose is used to fill oak tanks at California winery

ume, about 3 million lb this year. These chemicals have various other names indicative of their action: antiscorching agents, cure retarders, and prevulcanization inhibitors. Over time, the specific retarder used

in the largest volume changes, as has been the case with many rubber-processing chemicals. At one time, benzoic acid and a phenylamine derivative dominated the market. Now, *N*-(cyclohexylthio)phthalimide is

predominant because it doesn't stain, it works well with many antidegradants and accelerators, and it is relatively nontoxic. This and other compounds now used in smaller quantities have minor effects on the cure rate, on physical properties, and on degradation of the fabricated product. By far the largest use of retarders is in tire manufacturing, because they allow delays after assembly to give flexibility in the overall tire-production process.

A large number of other rubber-processing chemicals are used by fabricators, depending on the product they are making. To overcome the difficulties in mastication and dispersion of additives, many different plasticizers and softeners are used. Some are mixtures of natural products and act as lubricants. Others are plasticizers or peptizers and act chemically to retard repolymerization of chains broken during mastication. The peptizers are often thiophenols and are used in relatively

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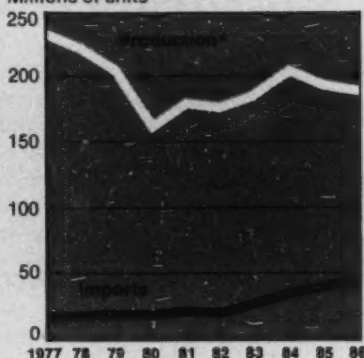
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U.S. tire production fell as imports rose

Millions of units



■ Passenger car plus truck and bus.

Sources: Rubber Manufacturers Association, Department of Commerce

low concentrations. Sales volume this year probably will total about 3 million lb.

Other materials added to rubber compounds as processing aids are diverse in composition. Some have little effect on properties of the finished rubber product; others may have major effects that are offset by use of still other additives. These materials range from common fatty acids to various esters, and the results of using them vary widely, depending on the rubber polymer. A variety of resins are used as aids in dispersion of fillers, reinforcing agents, and sulfur, and they may provide tack as an aid in assembly of the rubber product.

The diversity and complexity of rubber-processing chemicals have developed because of the importance of aids to making rubber products useful in almost all areas of consumer products. As consumer demands change, the processing chemicals to meet rubber fabricators' demands also will change. However, these changes will keep the rubber-processing chemicals industry viable and give producers options in their programs to improve profitability. The changes also are expected to provide returns on current R&D programs, through rapid increases in sales of new products. Fewer producers of rubber-processing chemicals may survive during the next decade, but those that remain could have a better business. □

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CIRCLE 6 ON READER SERVICE CARD

ACS Committee on Professional Training 1986 Annual Report

The number of bachelor's degree graduates in chemistry from colleges and universities whose undergraduate chemistry programs are approved by the American Chemical Society decreased 4.1% in the 1985-86 academic year from the previous year. The number of master's degrees from these departments stayed the same and the number of Ph.D. degrees continued to rise for the seventh year in a row, this year 4.2%. These departments project that in 1987 the number of bachelor's degrees will decrease 1.8%, master's will increase 9.6%, and Ph.D. degrees will increase 14.2%. (It should be noted, however, that these projections are usually higher than actual counts a year later.)

The percentage of baccalaureate graduates certified to ACS was 42%, the same as last year. (Certified graduates are those who have completed the curriculum specified by the Committee on Professional Training and are eligible for full membership in ACS; noncertified graduates may become associate

members of ACS upon graduation and full members after three years of professional experience or a higher degree in a chemical science.)

A total of 2269 of the bachelor's degree graduates from the approved schools were reported as planning to go to graduate school, and 1926 reported plans to go to professional schools.

Total numbers of bachelor's degrees (certified and noncertified), master's degrees, and Ph.D. degrees awarded in 1985-86 by departments whose chemistry programs are ACS approved are listed by institution in the large table at the end of this report and are summarized in the two smaller tables. These tables also include numbers of chemical engineering graduates from institutions whose programs are accredited by the American Institute of Chemical Engineers and the Accreditation Board for Engineering & Technology. (These departments are not required to report their data to CPT, so the number of departments includ-

Summary of totals from 1986 reports from approved schools

	Schools reporting	Men	Women	Total
CHEMISTRY				
Bachelors, total	580	5948	3347	9295
Certified		2512	1380	3892
Noncertified		3436	1967	5403
Masters	315	1056	564	1620
Doctorates	187	1496	389	1885
CHEMICAL ENGINEERING				
Bachelors, certified	118	3900	1329	5229
Masters	116	1023	221	1244
Doctorates	103	408	52	460

ed varies each year.) Included for the fourth year is a table with information on graduate student enrollments in chemistry departments whose undergraduate programs are ACS approved.

The number of bachelor's degrees in chemical engineering from the 118 AIChE-ABET-accredited departments that reported in 1986 decreased 23% from the total reported by 123 departments in 1985, the third decrease in a row. These 118 departments reported an expected further decrease in bachelor's degrees of 10.5% in 1987. At the graduate level, the number of chemical engineering master's degrees decreased for the first time and Ph.D. degrees increased for the seventh year in a row. The number of master's degrees was down 19% from 1985, and the number of Ph.D.s was up 9.1%. Projected 1987 numbers of master's and Ph.D. degrees in chemical engineering from these schools are up less than 1% for master's degrees and 32% for Ph.D.s.

The chemistry programs at ACS-approved schools normally are re-evaluated at five-year intervals. There were 580 colleges and univer-

Summary of data from approved schools, 1982-86

	Bachelors				Masters		Doctorates	
	Number of schools	Graduates (total)	Certified graduates	Noncertified graduates	Number of schools	Graduates	Number of schools	Graduates
CHEMISTRY								
1982	561	9,866	4179	5687	322	1046	187	1683
1983	570	10,043	4233	5810	320	1569	189	1759
1984	577	9,819	4201	5618	321	1637	189	1777
1985	579	9,679	4021	5658	316	1621	186	1806
1986	580	9,295	3892	5403	315	1620	187	1885
CHEMICAL ENGINEERING*								
1982	113	5,963	5963	—	109	1171	92	293
1983	122	7,021	7021	—	116	1317	101	333
1984	120	6,866	6866	—	114	1436	101	367
1985	123	6,442	6442	—	118	1489	104	418
1986	118	5,229	5229	—	116	1244	103	460

* Chemical engineering departments are not required to report their data to CPT, so the number of departments included in this category varies from year to year.

Graduate student enrollments in departments whose undergraduate chemistry programs are ACS approved

Number of departments	First-year graduate students		All graduate students	
	Full time	Part time	Full time	Part time
M.S. departments^a				
Fall 1982	131	494	310	1075
Fall 1983	132	452	293	1098
Fall 1984	131	468	270	1099
Fall 1985	129	364	229	930
Ph.D. departments				
Fall 1982	189	3412	306	13,488
Fall 1983	189	3554	275	14,037
Fall 1984	186	3404	227	14,194
Fall 1985	187	3947	501	15,576

^a Departments whose highest offering is the master's degree in chemistry.

Committee members, 1986

Alice J. Cunningham, chairwoman
 Agnes Scott College
Henry A. Benl
 North Carolina State University
Robert C. Braisted (deceased)
 University of Minnesota,
 Minneapolis
Marjorie C. Caserio
 University of California, Irvine
Michael P. Doyle
 Trinity University
C. David Gutsche
 Washington University
Gordon G. Hammes
 Cornell University
Herbert D. Kaez
 University of California, Los Angeles
Karen W. Mores
 Utah State University
Jere P. Segrest
 University of Alabama, Birmingham
Shelby W. Shelby
 Ethicon Inc.
Richard P. Van Dyne
 Northwestern University
Ernest L. Eikel, consultant
 University of North Carolina,
 Chapel Hill
Harry S. Gray, consultant
 California Institute of Technology
Peter Lykes, consultant
 Illinois Institute of Technology
Meivin B. Robin, consultant
 AT&T Bell Laboratories
Barbara A. Gallagher, committee secretary
Cathy A. Nelson, staff associate
Dolphine S. Hite, program assistant
 American Chemical Society

sities on the approved list at the end of 1986. During the year the committee studied the chemistry programs of 170 of the approved schools and of 19 schools applying for ACS approval. Each evaluation involved a review of extensive documentary materials submitted by the department chair describing the current status of the program.

Four schools were added to the ACS-approved list by CPT in 1986; two were put on probation; one was removed from probation; five continued on probation; and three were removed from the list. At year's end, 580 colleges and universities had ACS-approved undergraduate chemistry programs.

At its meeting in April 1986, the ACS Board of Directors unanimously endorsed the CPT proposal for development of a program for approval of alternate degrees. Subsequently, the committee has devoted considerable time and effort toward establishing guidelines for alternate degrees. In addition to the traditional bachelor's degrees in chemistry, guidelines for approved degrees with emphasis in biochemistry or polymer chemistry have been developed initially. Guidelines for chemistry degrees with other emphases are currently under consideration. The basic design is that of a required three years of studies for any chemistry and advanced or correlative study essential for the emphasis area.

In 1986 CPT marked its 50th anniversary with a symposium and reception during the ACS national

meeting in New York City. The symposium dealt with changes in higher education programs that accompany and must accommodate rapid changes in chemistry.

As part of the process of evaluating approved chemistry programs, the committee considers library journal holdings. To guide departments in developing chemistry libraries and to aid the committee's work, CPT has developed a list of recommended journals and related materials. This list will be made available in a 1987 edition of the *CPT Newsletter*.

Departments of forensic science and toxicology have requested that the ACS Directory of Graduate Research (DGR) be expanded to cover these disciplines. The committee has been reviewing programs in these areas in an effort to determine if the chemistry content of forensic science and toxicology programs warrants inclusion in the DGR.

Other CPT activities in 1986 included continued interaction with the ACS Society Committee on Education Task Force on ACS Involvement in the Two-Year Colleges; development of a program for a conference to address the concerns of small colleges on the ACS-approved list; review of the Target 2000 report; review of the Pimentel report, "Opportunities in Chemistry"; discussion of content of freshman general chemistry courses with the Division of Chemical Education; compilation of the responses to the science/chemistry building construction survey; participation in an electronic mail experiment; and continuation of a project to computerize all data received from ACS-approved schools.

The committee would like to acknowledge and thank the following visiting associates of the committee who conducted on-site visits to schools on the approved list or applying for ACS approval during 1986: Glenn A. Crosby, Washington State University; Roger L. DeKock, Calvin College; Arthur Fry, University of Arkansas; Heinz F. Koch, Ithaca College; William R. Moomaw, Williams College; Ronald M. Pike, Merrimack College; Jean'ne M. Shreeve, University of Idaho; Gene G. Wubbels, Grinnell College. □

Chemistry and chemical engineering degrees awarded by approved schools, 1985-86

	CHEMISTRY				CHEMICAL ENGINEERING					CHEMISTRY				CHEMICAL ENGINEERING			
	Bachelor's certified		M.S.	Ph.D.	B.S.		M.S.	Ph.D.		Bachelor's certified		M.S.	Ph.D.	B.S.		M.S.	Ph.D.
	Yes	No								Yes	No						
Ablene Christian U	2	3	3	—	—	—	—	—	Santa Barbara	24	9	9	22	a	—	—	—
Adelphi U	2	1	2	—	—	—	—	—	Santa Cruz	0	22	6	9	—	—	—	—
Agnes Scott C	2	1	—	—	—	—	—	—	Calvin C	6	6	—	—	—	—	—	—
Akron, U of	23	4	6	1	a	—	—	—	Canisius C	10	3	—	—	—	—	—	—
Alabama, U of	—	—	—	—	—	—	—	—	Capital U	2	5	—	—	—	—	—	—
University	2	11	1	5	32	4	0	—	Carleton C	3	27	—	—	—	—	—	—
Birmingham	1	2	5	1	—	—	—	—	Carnegie-Mellon U	20	2	10	4	52	12	11	—
Huntsville	0	5	1	—	a	—	—	—	Carroll C	4	10	—	—	—	—	—	—
Alaska, U of	6	0	3	—	—	—	—	—	Carthage C	2	3	—	—	—	—	—	—
Albion C	2	23	—	—	—	—	—	—	Case Western Reserve U	4	35	12	22	35	17	4	—
Albright C	1	15	—	—	—	—	—	—	Catholic U of America	0	0	0	4	a	—	—	—
Alfred U	1	0	—	—	—	—	—	—	Centenary C of Louisiana	1	2	—	—	—	—	—	—
Allegheny C	0	24	—	—	—	—	—	—	Central C	1	4	—	—	—	—	—	—
Alma C	2	7	—	—	—	—	—	—	Central Connecticut State U	5	0	0	—	—	—	—	—
American U	4	5	6	7	—	—	—	—	Central Florida, U of	14	0	6	—	—	—	—	—
Amherst C	0	10	—	—	—	—	—	—	Central Michigan U	5	18	5	—	—	—	—	—
Andrews U	3	9	—	—	—	—	—	—	Central State U	—	—	—	—	—	—	—	—
Appalachian State U	7	4	1	—	—	—	—	—	Ohio	2	3	—	—	—	—	—	—
Arizona State U	18	8	4	17	40	7	3	—	Oklahoma	4	7	—	—	—	—	—	—
Arizona, U of	25	30	12	15	33	10	3	—	Centre C	3	2	—	—	—	—	—	—
Arkansas, U of	—	—	—	—	—	—	—	—	Charleston, C of	7	4	—	—	—	—	—	—
Fayetteville	2	14	0	11	51	16	5	—	Chatham C	2	1	—	—	—	—	—	—
Little Rock	3	1	2	—	—	—	—	—	Chestnut Hill C	5	4	—	—	—	—	—	—
Ashland C	1	7	—	—	—	—	—	—	Chicago, U of	11	23	8	18	—	—	—	—
Auburn U	9	26	3	6	47	9	4	—	Christian Brothers C ^b	—	—	—	—	a	—	—	—
Augsburg C	4	8	—	—	—	—	—	—	Cincinnati, U of	22	0	20	13	53	11	1	—
Augustana C	—	—	—	—	—	—	—	—	Citadel, The	5	5	—	—	—	—	—	—
Illinois	1	14	—	—	—	—	—	—	City U of New York	—	—	—	18	—	—	—	—
South Dakota	2	9	—	—	—	—	—	—	Graduate Center	—	—	—	—	—	—	—	—
Austin C	1	8	—	—	—	—	—	—	Brooklyn C	0	31	2	—	—	—	—	—
Baldwin-Wallace C	1	8	—	—	—	—	—	—	City C	6	15	5	—	a	—	—	—
Ball State U	9	5	4	—	—	—	—	—	Herbert H. Lehman C	2	10	—	—	—	—	—	—
Barnard C	0	19	—	—	—	—	—	—	Hunter C	1	8	—	—	—	—	—	—
Bates C	3	10	—	—	—	—	—	—	Queens C	3	21	1	—	—	—	—	—
Baylor U	13	9	2	3	—	—	—	—	Clarion U of Pennsylvania	8	0	—	—	—	—	—	—
Beloit C	2	9	—	—	—	—	—	—	Clark U	3	3	7	1	—	—	—	—
Bemidji State U	4	4	—	—	—	—	—	—	Clarkson U	7	10	3	3	87	11	9	—
Birmingham-Southern C	5	15	—	—	—	—	—	—	Clemson U	7	3	2	1	57	7	1	—
Bloomsburg U	7	1	—	—	—	—	—	—	Cleveland State U	17	0	9	6	33	11	1	—
Boston C	19	0	7	3	—	—	—	—	Coe C	0	6	—	—	—	—	—	—
Boston U	4	19	7	8	—	—	—	—	Colby C	3	9	—	—	—	—	—	—
Bowdoin C	4	36	—	—	—	—	—	—	Colgate U	4	5	—	—	—	—	—	—
Bowling Green State U	5	9	4	—	—	—	—	—	Colorado C	4	5	—	—	—	—	—	—
Bradley U	3	7	0	—	—	—	—	—	Colorado School of Mines	14	0	4	1	84	18	2	—
Brandeis U	0	9	1	12	—	—	—	—	Colorado State U	19	13	3	17	24	11	0	—
Bridgeport, U of	1	0	5	—	—	—	—	—	Colorado, U of	—	—	—	—	—	—	—	—
Bridgewater State C	1	3	2	—	—	—	—	—	Boulder	6	46	7	14	52	13	4	—
Brigham Young U	9	33	1	8	53	6	2	—	Colorado Springs	9	2	—	—	—	—	—	—
Brown U	0	14	3	10	4	2	1	—	Denver	2	8	1	—	—	—	—	—
Bryn Mawr C	19	0	0	1	—	—	—	—	Columbia U	8	10	21	15	29	21	5	—
Bucknell U	6	12	6	—	29	2	—	—	Concordia C	3	7	—	—	—	—	—	—
Butler U	2	13	5	—	—	—	—	—	Connecticut, U of	26	13	3	11	59	14	1	—
California Institute of Tech	9	0	5	29	11	13	13	—	Cooper Union ^b	—	—	—	—	a	—	—	—
California Polytechnic State U	5	24	5	—	—	—	—	—	Cornell C	0	5	—	—	—	—	—	—
California State C	—	—	—	—	—	—	—	—	Cornell U	24	35	36	30	33	6	6	—
Bakersfield	6	2	—	—	—	—	—	—	Creighton U	0	18	3	—	—	—	—	—
Stanislaus	3	5	—	—	—	—	—	—	Dartmouth C	0	17	0	2	—	—	—	—
California State Polytechnic U	4	11	3	—	a	—	—	—	David Lipscomb C	0	13	—	—	—	—	—	—
California State U	—	—	—	—	—	—	—	—	Davidson C	4	5	—	—	—	—	—	—
Chico	2	12	—	—	—	—	—	—	Dayton, U of	7	9	1	—	33	4	—	—
Dominguez Hills	0	3	—	—	—	—	—	—	Delaware State C	1	2	—	—	—	—	—	—
Fresno	11	4	3	—	—	—	—	—	Delaware, U of	41	14	8	11	49	10	11	—
Fullerton	5	16	8	—	—	—	—	—	Delaware Valley C of	13	0	—	—	—	—	—	—
Hayward	13	4	2	—	—	—	—	—	Science & Agriculture	—	—	—	—	—	—	—	—
Long Beach	17	18	5	—	a	—	—	—	Delta State U	0	20	—	—	—	—	—	—
Los Angeles	12	0	5	—	—	—	—	—	Denison U	4	12	—	—	—	—	—	—
Northridge	10	13	2	—	—	—	—	—	Denver, U of	7	10	4	5	—	—	—	—
Sacramento	11	6	7	—	—	—	—	—	De Paul U	1	5	2	—	—	—	—	—
San Bernardino	0	5	—	—	—	—	—	—	DePaul U	7	11	—	—	—	—	—	—
California, U of	—	—	—	—	—	—	—	—	Detroit, U of	4	0	10	2	a	—	—	—
Berkeley	70	1	11	69	89	18	13	—	Dickinson C	1	16	—	—	—	—	—	—
Davis	30	7	2	15	34	3	3	—	Drake U	1	2	—	—	—	—	—	—
Irvine	18	48	7	17	—	—	—	—	Drew U	1	10	—	—	—	—	—	—
Los Angeles	27	73	12	29	11	8	5	—	Drexel U	14	0	11	3	67	7	4	—
Riverside	7	3	7	8	—	—	—	—	Duke U	15	44	0	13	—	—	—	—
San Diego	46	0	12	25	28	3	1	—	Duquesne U	3	5	5	1	—	—	—	—

	CHEMISTRY				CHEMICAL ENGINEERING			
	Bachelor's certified		M.S.	Ph.D.	B.S.	M.S.	Ph.D.	
	Yes	No						
Earlham C	0	8	—	—	—	—	—	
East Carolina U	7	1	0	—	—	—	—	
East Stroudsburg U	7	4	—	—	—	—	—	
East Tennessee State U	6	4	3	—	—	—	—	
East Texas State U	4	3	3	—	—	—	—	
Eastern Illinois U	5	3	4	—	—	—	—	
Eastern Kentucky U	2	14	2	—	—	—	—	
Eastern Michigan U	1	30	9	—	—	—	—	
Eastern New Mexico U	1	8	0	—	—	—	—	
Eckerd C	2	4	—	—	—	—	—	
Elizabethtown C	2	6	—	—	—	—	—	
Elmhurst C	1	15	—	—	—	—	—	
Emory U	2	43	4	8	—	—	—	
Emporia State U	0	4	0	—	—	—	—	
Evansville, U of	2	8	—	—	—	—	—	
Fairfield U	11	1	—	—	—	—	—	
Fairleigh Dickinson U								
Madison	12	0	2	—	—	—	—	
Teaneck	8	5	6	—	—	—	—	
Fisk U	8	0	2	—	—	—	—	
Florida Atlantic U	2	16	1	—	—	—	—	
Florida Institute of Tech	1	2	0	—	a	—	—	
Florida International U	9	6	—	—	—	—	—	
Florida State U	2	26	5	10	—	—	—	
Florida, U of	7	39	9	13	42	17	3	
Fordham U	1	9	2	—	—	—	—	
Fort Lewis C	2	16	—	—	—	—	—	
Franklin & Marshall C	8	8	—	—	—	—	—	
Furman U	20	5	4	—	—	—	—	
Geneva C	0	5	—	—	—	—	—	
George Mason U	9	1	—	—	—	—	—	
George Washington U	9	10	1	5	—	—	—	
Georgetown U	18	0	8	8	—	—	—	
Georgia Institute of Tech	12	0	4	14	100	24	9	
Georgia State U	2	8	4	—	—	—	—	
Georgia, U of	7	25	9	14	—	—	—	
Gettysburg C	2	7	—	—	—	—	—	
Glassboro State C	3	6	—	—	—	—	—	
Gonzaga U	0	0	—	—	—	—	—	
Goucher C	0	2	—	—	—	—	—	
Grand Valley State C	0	2	—	—	—	—	—	
Grinnell C	5	12	—	—	—	—	—	
Gustavus Adolphus C	5	8	—	—	—	—	—	
Hamilton C	1	4	—	—	—	—	—	
Hamline U	3	2	—	—	—	—	—	
Hampden-Sydney C	6	0	—	—	—	—	—	
Hampton U	8	0	3	—	—	—	—	
Hartford, U of	3	4	—	—	—	—	—	
Hartwick C	0	5	—	—	—	—	—	
Harvard U	—	31	18	36	—	—	—	
Harvey Mudd C	10	0	—	—	—	—	—	
Haverford C	2	7	—	—	—	—	—	
Hawaii, U of	7	4	1	6	—	—	—	
Hiram C	4	6	—	—	—	—	—	
Hobart & William Smith C	2	14	—	—	—	—	—	
Hofstra U	0	5	—	—	—	—	—	
Hollins C	0	1	—	—	—	—	—	
Holy Cross, C of The	11	11	—	—	—	—	—	
Hope C	20	11	—	—	—	—	—	
Houston, U of	10	2	9	9	a	—	—	
Howard U	24	0	8	6	23	4	—	
Humboldt State U	4	2	—	—	—	—	—	
Idaho State U	3	3	0	—	—	—	—	
Idaho, U of	2	3	6	3	33	9	1	
Illinois Benedictine C	11	0	—	—	—	—	—	
Illinois Institute of Tech	4	0	3	1	40	17	9	
Illinois State U	37	0	7	—	—	—	—	
Illinois, U of								
Chicago	29	21	22	13	a	—	—	
Urbana-Champaign	74	35	2	35	83	15	15	
Illinois Wesleyan U	1	3	—	—	—	—	—	
Indiana State U	12	0	3	—	—	—	—	
Indiana U	38	98	10	25	—	—	—	
Indiana U of Pennsylvania	11	8	3	—	—	—	—	
Indiana U at South Bend	5	1	—	—	—	—	—	
Indiana U Northwest	0	6	—	—	—	—	—	
Indiana U-Purdue U								
Fort Wayne	5	5	—	—	—	—	—	
Indianapolis	1	39	7	—	—	—	—	
Iowa State U	16	7	7	33	68	7	1	
Iowa, U of	10	2	9	9	26	5	3	
Ithaca C	6	0	—	—	—	—	—	
Jackson State U	4	1	2	—	—	—	—	
James Madison U	1	5	—	—	—	—	—	
John Carroll C	4	26	1	—	—	—	—	
Johns Hopkins U	8	6	6	10	16	3	8	
Juniata C	3	13	—	—	—	—	—	
Kalamazoo C	3	16	—	—	—	—	—	
Kansas State U	6	1	3	9	23	4	2	
Kansas, U of	10	22	2	8	38	8	2	
Kean C of New Jersey	6	3	—	—	—	—	—	
Kearney State C	2	3	—	—	—	—	—	
Kent State U	14	7	1	4	—	—	—	
Kentucky, U of	16	18	3	2	48	9	2	
Kenyon C	4	9	—	—	—	—	—	
King's C	5	3	—	—	—	—	—	
Knox C	0	20	—	—	—	—	—	
Lafayette C	4	9	—	—	34	—	—	
Lake Forest C	3	4	—	—	—	—	—	
Lamar U	4	2	5	—	23	2	2	
La Salle C	2	0	—	—	—	—	—	
Lawrence Institute of Tech	6	0	—	—	—	—	—	
Lawrence U ^c	5	3	9	4	—	—	—	
Lebanon Valley C	4	5	—	—	—	—	—	
Lehigh U	22	0	13	11	33	26	11	
Le Moyne C	6	0	—	—	—	—	—	
Lewis & Clark C	0	7	—	—	—	—	—	
Lincoln U	1	8	—	—	—	—	—	
Long Island U								
Brooklyn Center	0	6	0	—	—	—	—	
C. W. Post C	3	0	—	—	—	—	—	
Loras C	2	1	—	—	—	—	—	
Louisiana State U								
Baton Rouge	5	11	2	10	45	11	2	
Shreveport	3	0	—	—	—	—	—	
Louisiana Tech U	4	0	2	—	a	—	—	
Louisville, U of	6	17	1	4	26	11	3	
Lowell, U of	8	1	4	8	32	5	—	
Loyola C	4	2	—	—	—	—	—	
Loyola Marymount U	3	4	—	—	—	—	—	
Loyola U								
New Orleans	1	1	—	—	—	—	—	
Chicago	11	15	5	3	—	—	—	
Luther C	0	3	—	—	—	—	—	
Macalester C	3	3	—	—	—	—	—	
Maine, U, at Orono	6	5	2	1	34	2	2	
Manhattan C ^d	12	1	—	—	49	30	—	
Manhattanville C	2	0	—	—	—	—	—	
Mankato State U	12	7	1	—	—	—	—	
Marietta C	4	0	—	—	—	—	—	
Marist C	0	3	—	—	—	—	—	
Marquette U	4	0	6	9	—	—	—	
Marshall U	4	20	2	—	—	—	—	
Maryland, U of								
College Park	19	60	12	22	a	—	—	
Baltimore County	10	20	5	—	—	—	—	
Massachusetts Institute of Tech	42	0	2	38	54	35	27	
Massachusetts, U of	11	6	3	12	32	8	6	
McNeese State U	6	0	4	—	—	—	—	
Memphis State U	3	4	0	1	—	—	—	
Mercer U	4	3	—	—	—	—	—	
Merrimack C	1	2	—	—	—	—	—	
Metropolitan State C	8	21	—	—	—	—	—	
Miami U	21	32	3	9	—	—	—	
Miami, U of	0	52	2	3	—	—	—	
Michigan State U	18	17	10	36	50	15	4	
Michigan Technological U	18	0	3	0	71	a	2	
Michigan, U of								
Ann Arbor	63	0	29	28	73	6	6	
Dearborn	10	5	—	—	—	—	—	
Flint	1	10	—	—	—	—	—	
Middle Tennessee State U	0	24	3	—	—	—	—	
Middlebury C	0	9	0	—	—	—	—	
Midwestern State U	1	7	—	—	—	—	—	
Millersville U	1	10	—	—	—	—	—	
Millsaps C	2	12	—	—	—	—	—	
Minnesota, U of								
Minneapolis	36	0	6	20	98	3	18	
Duluth	8	20	4	—	—	—	—	
Mississippi C	3	4	—	—	—	—	—	

CIRCLE 61 ON READER SERVICE CARD →

	CHEMISTRY				CHEMICAL ENGINEERING			
	Bachelor's certified		M.S.	Ph.D.	B.S.	M.S.	Ph.D.	
	Yes	No						
Mississippi State U	0	0	3	3	44	3	2	
Mississippi, U of	2	6	2	1	14	5	1	
Missouri, U of								
Columbia	12	4	9	1	22	9	2	
Kansas City	9	14	1	5	—	—	—	
Rolla	12	0	5	6	110	16	3	
St. Louis	12	11	6	2	—	—	—	
Missouri Western State C	2	0	—	—	—	—	—	
Monmouth C								
Illinois	3	3	—	—	—	—	—	
New Jersey	3	0	—	—	—	—	—	
Montana C of Mineral	3	1	2	—	—	—	—	
Science & Tech								
Montana State U	2	9	3	5	49	14	2	
Montana, U of	5	5	3	2	—	—	—	
Montclair State C	7	12	3	—	—	—	—	
Moorhead State U	3	5	—	—	—	—	—	
Moravian C	2	3	—	—	—	—	—	
Morehouse C*	4	1	6	3	—	—	—	
Morgan State U	3	1	—	—	—	—	—	
Mount Holyoke C	0	10	1	1	—	—	—	
Mount Saint Vincent, C of ^d	0	0	—	—	—	—	—	
Muhlenberg C	0	22	—	—	—	—	—	
Murray State U	4	11	1	—	—	—	—	
Muskingum C	2	7	—	—	—	—	—	
Nebraska, U of								
Lincoln	3	13	5	11	30	12	0	
Omaha	5	5	—	—	—	—	—	
Nebraska Wesleyan U	6	5	—	—	—	—	—	
Nevada, U of								
Las Vegas	0	8 ^b	0	—	—	—	—	
Reno	2	3	2	2	—	—	—	
New Hampshire, U of	10	6	7	3	a	—	—	
New Jersey Institute of Tech ^b	—	—	—	—	66	14	3	
New Mexico Highlands U	0	0	0	—	—	—	—	
New Mexico Institute of	9	0	7	—	—	—	—	
Mining & Tech								
New Mexico State U	7	16	4	7	30	4	1	
New Mexico, U of	8	6	9	4	19	8	4	
New Orleans, U of	5	8	2	3	—	—	—	
New York U	5	40	19	9	—	—	—	
Niagara U	0	12	—	—	—	—	—	
North Alabama, U of	2	8	—	—	—	—	—	
North Carolina A&T State U	4	0	5	—	—	—	—	
North Carolina Central U	0	5	3	—	—	—	—	
North Carolina State U	21	24	5	7	102	3	2	
North Carolina, U of								
Asheville	3	1	—	—	—	—	—	
Chapel Hill	40	79	9	26	—	—	—	
Charlotte	2	5	2	—	—	—	—	
Greensboro	5	5	3	—	—	—	—	
Wilmington	8	8	—	—	—	—	—	
North Dakota State U	1	20	6	5	—	—	—	
North Dakota, U of	7	3	1	6	33	4	—	
North Texas State U	4	5	8	7	—	—	—	
Northeast Louisiana U	2	1	2	—	—	—	—	
Northeastern Illinois U	2	13	5	—	—	—	—	
Northeastern U	4	0	11	7	a	—	—	
Northern Arizona U	3	12	0	—	—	—	—	
Northern Colorado, U of	1	8	1	1	—	—	—	
Northern Illinois U	10	11	3	4	—	—	—	
Northern Iowa, U of	4	20	1	—	—	—	—	
Northern Kentucky U	3	6	—	—	—	—	—	
Northern Michigan U	3	6	0	—	—	—	—	
Northwest Missouri State U	4	0	—	—	—	—	—	
Northwestern State U of	0	1	—	—	—	—	—	
Louisiana								
Northwestern U	10	15	29	21	41	40	11	
Norwich U	1	0	—	—	—	—	—	
Notre Dame, U of	6	9	3	8	50	11	9	
Oakland U	6	3	0	—	—	—	—	
Oberlin C	0	15	—	—	—	—	—	
Occidental C	6	8	—	—	—	—	—	
Ohio Northern U	5	5	—	—	—	—	—	
Ohio State U	33	0	16	30	56	21	3	
Ohio U	5	6	4	5	23	8	0	
Ohio Wesleyan U	0	6	—	—	—	—	—	
Oklahoma State U	3	1	3	11	26	15	4	
Oklahoma, U of	9	24	10	11	39	20	2	
Old Dominion U	11	7	5	—	—	—	—	

	CHEMISTRY				CHEMICAL ENGINEERING			
	Bachelor's certified		M.S.	Ph.D.	B.S.	M.S.	Ph.D.	
	Yes	No						
Oregon State U	22	0	3	6	41	6	0	
Oregon, U of	6	29	6	10	—	—	—	
Pace U	4	2	—	—	—	—	—	
Pacific Lutheran U	3	9	—	—	—	—	—	
Pacific, U of The	1	3	2	0	—	—	—	
Pennsylvania State U	6	33 ^b	10	24	165	17	9	
Pennsylvania, U of	6	28	9	15	35	19	6	
Philadelphia C of Pharmacy	3	0	3	0	—	—	—	
& Science								
Philadelphia C of Textiles &	1	0	—	—	—	—	—	
Sciences								
Pittsburg State U	4	2	3	—	—	—	—	
Pittsburgh, U of	25	52	10	16	83	13	4	
Polytechnic U	6	0	6	12	37	5	6	
Pomona C	1	5	—	—	—	—	—	
Portland State U	4	10	0	2	—	—	—	
Pratt Institute ^b	—	—	—	—	a	—	—	
Princeton U	21	12	20	21	17	5	10	
Providence U	5	5	0	0	—	—	—	
Puerto Rico, U of								
Mayaguez	21	6	3	—	63	6	—	
Rio Piedras	15	43	5	1	—	—	—	
Puget Sound, U of	7	4	—	—	—	—	—	
Purdue U	59	30	11	32	128	18	10	
Purdue U Calumet	9	2	—	—	—	—	—	
Randolph-Macon Woman's C	0	4	—	—	—	—	—	
Ramapo C of New Jersey	1	6	—	—	—	—	—	
Redlands, U of	1	1	—	—	—	—	—	
Reed C	16	0	—	—	—	—	—	
Rensselaer Polytechnic Inst	25	0	26	14	51	14	9	
Rhode Island, U of	7	1	2	5	39	4	1	
Rhodes C	1	9	—	—	—	—	—	
Rice U	3	7	20	11	20	12	9	
Richmond, U of	3	14	0	0	—	—	—	
Rider C	1	0	—	—	—	—	—	
Ripon C	3	3	—	—	—	—	—	
Roanoke C	6	1	—	—	—	—	—	
Rochester Institute of Tech	5	9	10	—	—	—	—	
Rochester, U of	26	0	23	19	20	15	4	
Rollins C	5	1	—	—	—	—	—	
Roosevelt U	5	1	7	—	—	—	—	
Rose-Hulman Institute of Tech	11	0	—	—	69	6	—	
Russell Sage C	1	1	—	—	—	—	—	
Rutgers U								
New Brunswick	48	31	9	15	71	20	3	
Camden C	1	11	—	—	—	—	—	
Newark C of Arts & Sciences	4	7	4	4	—	—	—	
Saginaw Valley State C	1	13	—	—	—	—	—	
St. Anselm C	1	2	—	—	—	—	—	
St. Catherine, C of	2	8	—	—	—	—	—	
St. Cloud State U	1	9	—	—	—	—	—	
St. John Fisher C	9	1	—	—	—	—	—	
St. John's U	7	4	4	—	—	—	—	
St. John's U/C of St. Benedict	4	11	—	—	—	—	—	
St. Joseph C	2	0	6	—	—	—	—	
St. Joseph's U	3	21	8	—	—	—	—	
St. Lawrence U	1	15	—	—	—	—	—	
St. Louis U	6	21	3	—	—	—	—	
St. Mary's C	1	2	—	—	—	—	—	
St. Michael's C	0	2	—	—	—	—	—	
St. Olaf C	7	38	—	—	—	—	—	
St. Peter's C	3	2	—	—	—	—	—	
St. Thomas, C of	1	9	—	—	—	—	—	
Salem State C	2	1	—	—	—	—	—	
Sam Houston State U	10	0	3	—	—	—	—	
San Diego State U	18	0	18	2	—	—	—	
San Francisco State U	6	24	2	—	—	—	—	
San Francisco, U of	4	2	2	—	—	—	—	
San Jose State U	13	20	6	—	a	—	—	
Sangamon State U	3	0	—	—	—	—	—	
Santa Clara, U of	2	5	—	—	—	—	—	
Scranton, U of	6	9	9	—	—	—	—	
Seattle U	2	3	—	—	—	—	—	
Seton Hall U	7	10	11	7	—	—	—	
Shippensburg U	6	4	4	—	—	—	—	
Siena C	2	1	—	—	—	—	—	
Simmons C	1	1	—	—	—	—	—	
Skidmore C	2	24	—	—	—	—	—	
Smith C	8	0	0	0	—	—	—	
Sonoma State U	3	22	—	—	—	—	—	

	CHEMISTRY				CHEMICAL ENGINEERING			
	Bachelor's certified		M.S.	Ph.D.	B.S.		M.S.	Ph.D.
	Yes	No						
South Alabama, U of ^a	—	—	—	—	a	—	—	—
South Carolina, U of	4	27	5	24	27	7	0	—
South Dakota School of Mines & Tech	5	0	1	—	34	6	—	—
South Dakota State U	1	26	0	—	—	—	—	—
South Dakota, U of	2	9	2	—	—	—	—	—
South Florida, U of	16	47	1	2	28	4	1	—
Southeast Missouri State U	1	7	—	—	—	—	—	—
Southeastern Louisiana U	0	1	—	—	—	—	—	—
Southeastern Massachusetts U	7	5	6	—	—	—	—	—
Southern California, U of	14	5	2	12	28	5	3	—
Southern Colorado U	1	2	—	—	—	—	—	—
Southern Illinois U	—	—	—	—	—	—	—	—
Carbondale	6	5	8	6	—	—	—	—
Edwardsville	12	6	3	—	—	—	—	—
Southern Methodist U	5	0	0	—	—	—	—	—
Southern Mississippi, U of	1	10	4	0	—	—	—	—
Southern Oregon State C	1	15	—	—	—	—	—	—
Southern U & A&M C	7	0	0	—	—	—	—	—
Southwest Missouri State U	0	14	—	—	—	—	—	—
Southwest State U	1	1	—	—	—	—	—	—
Southwest Texas State U	10	1	1	—	—	—	—	—
Southwestern Louisiana, U of	0	12	—	—	a	—	—	—
Southwestern Oklahoma State U	3	3	—	—	—	—	—	—
Stanford U	9	9	1	23	14	13	9	—
State U of New York	—	—	—	—	—	—	—	—
Albany	10	9	5	5	—	—	—	—
Binghamton	10	27	1	10	—	—	—	—
Buffalo	19	9	9	17	70	15	6	—
Stony Brook	19	23	5	12	—	—	—	—
C at Brockport	3	6	—	—	—	—	—	—
C at Buffalo	6	8	1	—	—	—	—	—
C at Cortland	0	14	—	—	—	—	—	—
C at Fredonia	5	5	0	—	—	—	—	—
C at Geneseo	6	0	—	—	—	—	—	—
C at New Paltz	4	3	2	—	—	—	—	—
C at Oneonta	1	16	0	—	—	—	—	—
C at Oswego	21	7	3	—	—	—	—	—
C at Plattsburgh	7	13	2	—	—	—	—	—
C at Potsdam	0	15	—	—	—	—	—	—
Stephen F. Austin State U	4	1	0	—	—	—	—	—
Stetson U	4	1	—	—	—	—	—	—
Stevens Institute of Tech	2	4	17	1	7	11	4	—
Suffolk U	1	2	—	—	—	—	—	—
Susquehanna U	1	1	—	—	—	—	—	—
Swarthmore C	3	8	—	—	—	—	—	—
Syracuse U	10	6	0	5	18	12	1	—
Temple U	9	3	2	1	—	—	—	—
Tennessee Technological U	3	10	2	—	37	6	0	—
Tennessee, U of	—	—	—	—	—	—	—	—
Knoxville	3	7	8	9	60	9	4	—
Martin	3	8	—	—	—	—	—	—
Chattanooga	12	7	—	—	—	—	—	—
Texas A&I U	6	1	2	—	10	4	—	—
Texas A&M U	10	12	9	24	122	25	3	—
Texas Christian U	1	25	0	4	—	—	—	—
Texas Southern U	15	0	10	—	—	—	—	—
Texas Technological U	8	11	7	7	40	12	1	—
Texas, U of	—	—	—	—	—	—	—	—
Arlington	8	12	4	2	—	—	—	—
Austin	44	0	14	41	105	20	11	—
Dallas	6	0	2	1	—	—	—	—
El Paso	5	0	12	—	—	—	—	—
Texas Woman's U	1	3	1	1	—	—	—	—
Thiel C	2	4	—	—	—	—	—	—
Thomas More C	2	0	—	—	—	—	—	—
Toledo, U of	1	9	2	3	26	8	1	—
Towson State U	4	5	—	—	—	—	—	—
Trenton State C	8	0	—	—	—	—	—	—
Trinity C	4	7	0	—	—	—	—	—
Trinity U	1	8	—	—	—	—	—	—
Tri-State U ^b	—	—	—	—	a	—	—	—
Tufts U	0	20	1	2	28	9	2	—
Tulane U of Louisiana	1	14	1	6	19	3	1	—
Tulsa, U of	1	0	—	—	32	8	2	—
Tuskegee U	0	5	4	—	8	—	—	—
Union C	4	12	—	—	—	—	—	—
U.S. Air Force Academy	6	7	—	—	—	—	—	—
U.S. Naval Academy	10	5	—	—	—	—	—	—
Ursinus C	5	16	—	—	—	—	—	—

	CHEMISTRY				CHEMICAL ENGINEERING			
	Bachelor's certified		M.S.	Ph.D.	B.S.		M.S.	Ph.D.
	Yes	No						
Utah State U	9	0	3	2	—	—	—	—
Utah, U of	5	31	5	19	a	—	—	—
Valparaiso U	5	30	—	—	—	—	—	—
Vanderbilt U	0	32	5	8	23	7	0	—
Vassar C	0	8	0	—	—	—	—	—
Vermont, U of	12	0	2	5	—	—	—	—
Villanova U	15	0	6	3	21	15	—	—
Virginia Commonwealth U	7	18	2	6	—	—	—	—
Virginia Military Institute	5	0	—	—	—	—	—	—
Virginia Polytechnic Institute & State U	22	14	8	16	72	3	3	—
Virginia, U of	7	92	9	10	28	31	2	—
Wabash C	9	9	—	—	—	—	—	—
Wagner C	1	7	—	—	—	—	—	—
Wake Forest U	13	18	1	1	—	—	—	—
Washburn U of Topeka	2	1	—	—	—	—	—	—
Washington C	4	0	—	—	—	—	—	—
Washington & Jefferson C	2	18	—	—	—	—	—	—
Washington & Lee U	0	9	—	—	—	—	—	—
Washington State U	11	7	14	7	26	6	3	—
Washington U	0	7	12	2	42	13	3	—
Washington, U of	41	17	7	11	41	11	4	—
Wayne State U	15	30	8	15	37	18	2	—
Waynesburg C	4	2	—	—	—	—	—	—
Weber State C	6	8	—	—	—	—	—	—
Wellesley C	5	29	—	—	—	—	—	—
Wesleyan U	4	16	1	4	—	—	—	—
West Chester U	7	15	0	—	—	—	—	—
West Florida, U of	3	7	—	—	—	—	—	—
West Texas State U	0	4	1	—	—	—	—	—
West Virginia Institute of Tech ^b	—	—	—	—	20	0	—	—
West Virginia State C	1	7	—	—	—	—	—	—
West Virginia U	12	46	4	4	43	9	8	—
Western Illinois U	5	2	4	—	—	—	—	—
Western Kentucky U	3	11	7	—	—	—	—	—
Western Maryland C	2	5	—	—	—	—	—	—
Western Michigan U	7	14	5	0	—	—	—	—
Western New England C	2	0	—	—	—	—	—	—
Western Washington U	8	19	1	—	—	—	—	—
Westminster C	0	5	—	—	—	—	—	—
Wheaton C	—	—	—	—	—	—	—	—
Illinois	2	18	—	—	—	—	—	—
Massachusetts	4	3	—	—	—	—	—	—
Wheeling C	0	2	—	—	—	—	—	—
Whitman C	3	7	—	—	—	—	—	—
Whittier C	2	6	—	—	—	—	—	—
Wichita State U	11	11	3	—	—	—	—	—
Widener U	0	0	—	—	13	2	—	—
Wilkes C	2	0	—	—	—	—	—	—
Willamette U	3	4	—	—	—	—	—	—
William Paterson C of N.J.	0	5	—	—	—	—	—	—
William & Mary, C of	24	5	5	—	—	—	—	—
Williams C	0	24	—	—	—	—	—	—
Wisconsin, U of	—	—	—	—	—	—	—	—
Eau Claire	5	4	—	—	—	—	—	—
Green Bay	0	12	—	—	—	—	—	—
La Crosse	5	13	—	—	—	—	—	—
Madison	17	17	14	44	99	6	12	—
Milwaukee	4	19	11	7	—	—	—	—
Oshkosh	5	5	—	—	—	—	—	—
Parkside	5	1	—	—	—	—	—	—
Platteville	1	1	—	—	—	—	—	—
River Falls	3	8	—	—	—	—	—	—
Stevens Point	8	4	—	—	—	—	—	—
Superior	3	2	—	—	—	—	—	—
Wittenberg U	1	5	—	—	—	—	—	—
Wooster, C of	0	23	—	—	—	—	—	—
Worcester Polytechnic Institute	10	4	0	1	41	8	1	—
Wright State U	21	11	10	—	—	—	—	—
Wyoming, U of	0	1	1	4	14	13	2	—
Xavier U	4	8	2	—	—	—	—	—
Xavier U of Louisiana	1	31	—	—	—	—	—	—
Yale U	12	0	24	19	a	—	—	—
Youngstown State U	13	29	10	—	a	—	—	—
TOTALS	3692	5403	1620	1685	5229	1244	460	—

Note: For brevity, "D.S." and "M.S." are used to denote all bachelor's and master's degrees, respectively, in each column. a Data not submitted. b Listed on basis of accreditation by AIChE-ABET. c Master's and Ph.D. degrees given by the Institute of Paper Chemistry. d The chemistry programs at Mount Saint Vincent and Manhattan College are integrated into a combined department with all instruction in chemistry located at Manhattan College. e Master's and Ph.D. degrees given by Atlanta University.

Indiana remains top producer of chemists

Indiana University graduated more B.S. chemists (136) in the 1985-86 academic year than any other school in the country, as it did in the previous academic year. The University of North Carolina, Chapel Hill, remained in second place with 119. The University of Illinois, Champaign-Urbana, retained the third spot with 109.

The biggest producer of new Ph.D. chemists in 1985-86 was the University of California, Berkeley, as it had been in 1984-85, with 69. The University of Wisconsin, Madison, moved up from fourth the previous year to second with 44 graduates. And the University of Texas, Austin, climbed from 10th to take third place with 41.

These are some of the data gleaned by C&EN from the latest annual report of ACS's Committee on Professional Training (see page 59). This committee is charged with setting standards for undergraduate chemistry education and monitoring them. It also collects data annually from departments with programs it approves on the number of new chemistry graduates at all levels.

According to the new report, the University of Illinois, Urbana-Champaign, was the largest producer in 1985-86 of new chemists with undergraduate degrees certified by ACS. The University of California, San Diego, the 1984-85 leader, dropped to sixth. Certified graduates are immediately eligible for ACS membership.

The distinction of being the largest producer of new Ph.D. chemists has been shared for the past 13 years exclusively by the University of California, Berkeley, five times, including last year, and Illinois, Urbana-Champaign, eight times. In 1985-86, however, the Illinois school slipped to seventh.

Cornell University was the largest producer of M.S. chemists with 36 in 1985-86. Second was the University of Michigan, Ann Arbor, with 29. In 1984-85 these two schools shared the lead in this category, each with 31 graduates.

Michael Heylin, Washington

These schools had most chemistry graduates, 1985-86

Total bachelor graduates

1. Indiana U	136
2. U of North Carolina, Chapel Hill	119
3. U of Illinois, Urbana-Champaign	109
4. U of California, Los Angeles	100
5. U of Virginia	99
6. Purdue U	89
7. U of Maryland, College Park	79
7. Rutgers U	79
9. U of Pittsburgh	77
10. U of California, Berkeley	71
11. U of California, Irvine	66
12. U of Michigan, Ann Arbor	63
12. U of South Florida	63
14. Cornell U	59
14. Duke U	59
16. U of Puerto Rico, Rio Piedras	58
16. U of Washington	58
16. West Virginia U	58
19. U of Arizona	55
19. U of Delaware	55
21. Miami U	53
22. U of Colorado, Boulder	52
22. U of Miami	52
24. U of Illinois, Chicago	50
25. U of California, San Diego	46
25. U of Florida	46

Certified bachelor graduates

1. U of Illinois, Urbana-Champaign	74
2. U of California, Berkeley	70
3. U of Michigan	63
4. Purdue U	59
5. Rutgers U	48
6. U of California, San Diego	48
7. U of Texas, Austin	44
8. Massachusetts Inst of Tech	42
9. U of Delaware	41
9. U of Washington	41
11. U of North Carolina, Chapel Hill	40
12. Indiana U	38
13. Illinois State U	37
14. U of Minnesota	36
15. Ohio State U	33
16. U of California, Davis	30
17. U of Illinois, Chicago	29
18. U of California, Los Angeles	27
19. U of Connecticut	26
19. U of Rochester	26
21. U of Arizona	25
21. U of Pittsburgh	25
21. Rensselaer Polytechnic Inst	25
24. U of California, Santa Barbara	24
24. Cornell U	24
24. Howard U	24
24. C of William & Mary	24

Masters graduates

1. Cornell U	36
2. U of Michigan	29
3. Northwestern U	29
4. Rensselaer Polytechnic Inst	26
5. Yale U	24
6. U of Rochester	23
7. U of Illinois, Chicago	22
8. Columbia U	21
9. U of Cincinnati	20
9. Princeton U	20
9. Rice U	20
12. New York U	19
13. Harvard U	18
13. San Diego State U	18
15. Stevens Inst of Tech	17
16. Ohio State U	16
17. U of Texas, Austin	14
17. Washington State U	14
17. U of Wisconsin, Madison	14
20. Lehigh U	13
21. U of Arizona	12
21. U of California, Los Angeles	12
21. U of California, San Diego	12
21. Case Western Reserve U	12
21. U of Maryland, College Park	12
21. U of Texas, El Paso	12
21. Washington U	12

Doctoral graduates

1. U of California, Berkeley	69
2. U of Wisconsin, Madison	44
3. U of Texas, Austin	41
4. Massachusetts Inst of Tech	38
5. Harvard U	36
5. Michigan State U	36
7. U of Illinois, Urbana-Champaign	35
8. Iowa State U	33
9. Purdue U	32
10. Cornell U	30
10. Ohio State U	30
12. California Inst of Tech	29
12. U of California, Los Angeles	29
14. U of Michigan, Ann Arbor	28
15. U of North Carolina, Chapel Hill	26
16. U of California, San Diego	25
16. Indiana U	25
18. Pennsylvania State U	24
18. U of South Carolina	24
18. Texas A&M U	24
21. Stanford U	23
22. U of California, Santa Barbara	22
22. Case Western Reserve	22
22. U of Maryland, College Park	22
25. Northwestern U	21
25. Princeton U	21

New technologies emerge for
hazardous waste cleanup
Page 7

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**Frank H.
Westheimer
wins 1988
Priestley Medal
Page 21**

News of the Week

■ **NRC panel urges EPA to adopt a uniform standard for setting tolerance limits for pesticide residues on food.** Page 4

■ **Danish scientists discover material that makes aging skin cells both appear and act like younger cells.** Page 5

■ **Use of proposed manned space station is the subject of a dispute between Congress and the Defense Department.** Page 5

■ **Frank Popoff, new president and chief operating officer of Dow Chemical, has the confidence of business analysts that he will continue the company's earnings growth.** Page 6

■ **MIT's hazardous substance program will attempt to integrate research at the institute, apply it to real-world problems.** Page 6

Business

First-quarter gains in sales, profits of major pharmaceutical firms are attributed to improved exports owing to weaker dollar. Page 15

Government

Study indicates that NSF's support of academic basic chemical research is lacking, making talented chemists abandon the discipline. Page 17

Substitutes for chlorofluorocarbons are ready to be commercialized, but their high price offsets their environmental aspects. Page 18

Priestley Medal

Frank H. Westheimer, professor emeritus at Harvard University, is the 1988 recipient of ACS's Priestley Medal. Page 21

Education

London Science Museum's Chemical Industry Gallery aims at making the public aware of the industry's evolution, using cartoon characters, exhibits of early processes, hands-on computer modeling. Page 24

ACS News

American Chemical Society honors 50-year members; each receives a certificate, a pin, and free registration at meetings. Page 26

Awards

ACS Division of Biological Chemistry will honor three awardees for their excellence in research at New Orleans national meeting. Page 31

Cover: Photo by C&EN's David J. Hanson

Letters 2

Concentrates

Business 13

Government 16

Science/Technology 19

The Departments

Meetings 33

Newsclips 48



News Focus

New techniques for treating hazardous wastes will be demonstrated, mainly at Superfund sites, for cost/performance evaluation by EPA. Page 7

Profitability Rises at Major Drug Firms

Higher unit sales, better operating efficiencies, lower raw material costs, and much improved exports all served to raise sales, earnings, and profitability among major pharmaceutical firms in the first quarter over the same period in 1986.

A group of 15 major drug companies surveyed by C&EN had an average earnings gain of 21% and an average sales increase of 11%. Of the 15 companies, all but one had earnings increases of 10% or more. And only four of the companies had sales gains less than 10%. Profit margins (earnings from continuing operations, excluding major nonrecurring and extraordinary items, as a percentage of sales) for the group averaged 13.2% in the first quarter, compared with 12.2% in first-quarter 1986.

The foreign trade situation was important for many of the companies. Pfizer, for instance, notes that the weaker dollar had a favorable impact on reported results. The effect of currency translation improved its worldwide sales growth from 4 to 8% in the first quarter.

The company also says that net income benefited significantly from currency fluctuations. Pfizer reported a 14% increase in earnings for the quarter to \$192 million on an 8% sales increase to \$1.12 billion.

Becton Dickinson is another company whose international sales boosted its first-quarter performance. Overall, the firm posted a 9% earnings gain to \$36.5 million on a 22% sales rise to \$390 million. The company says that on a geographic basis sales increased 12% in the U.S. to \$255 million, but overseas sales shot up 48% to \$135 million.

For Bristol-Myers, earnings increased 20% to \$174 million on a 13% sales gain to \$1.35 billion. According to chairman Richard L. Gelb, the sales increase for the quarter was a result of balanced growth in both domestic and international businesses. Exchange rate fluctuations did contribute about 1% to total sales growth, though, he says.

Schering-Plough, although admitting that it benefited from currency rate fluctuations, attributes its earnings

growth to other reasons. Its earnings increased 18% to \$84.9 million on a 12% sales gain to \$686 million. Chairman and chief executive officer Robert P. Luciano says the firm's higher earnings resulted from a strong performance by the pharmaceuticals business and continued cost controls and improvements in operating and production efficiencies.

At Warner-Lambert, total sales were up 10% to \$822 million, and earnings rose 13% to \$73.4 million.

Warner-Lambert's chairman Joseph D. Williams attributed that firm's 13% earnings gain to several factors, including good sales performance, a lower raw materials cost, a lower effective tax rate, and reduced pension expenses resulting from adoption of new pension accounting standards.

Merck posted a 28% increase in earnings to \$201 million on a 21% sales gain to \$1.11 billion. Of those increases, chairman and chief executive officer P. Roy Vagelos says, "Income growth and improved earnings margins resulted from strong unit volume gains, a better product mix, the continuation of cost controls and productivity improvements, as well as the favorable rate of exchange."

If the first quarter is any indication, 1987 will turn out to be a good year for drug makers. At least company executives see it this way. For instance, Richard M. Furlaud, chairman of Squibb, says, "Results for the first quarter indicate that results for full-year 1987 probably will tend toward the upper end of the range of our previously announced expectations of 30 to 35% growth in earnings per share."

And at Warner-Lambert, chairman Williams told the company's annual meeting that the 17% earnings-per-share gain to \$1.02 in the first quarter of this year helps set the tone for the company's performance for all of 1987.

William Storck, New York

Pharmaceutical first-quarter earnings increased sharply

	FIRST-QUARTER 1987				Profit margin ^b	
	Sales (\$ millions)	Earnings ^a	Change from 1986		1987	1986
American Home Products	\$ 1,288.4	\$ 216.5	2%	10%	16.8%	15.9%
Baxter Travenol	1,407.0	84.0	6	89	4.5	2.6
Becton Dickinson	390.0	36.5	22	9	9.4	10.5
Bristol-Myers	1,347.9	173.9	13	20	12.9	12.1
EL Lilly	1,059.0	205.2	7	19	19.4	17.5
Johnson & Johnson	1,980.3	235.5	14	19	11.9	11.4
Merck	1,111.1	201.3	21	28	18.1	17.1
Pfizer	1,119.6	192.0	8	14	17.1	16.4
A. H. Robins	209.8	26.0	10	16	12.4	11.7
Schering-Plough	689.3	84.9	12	18	12.4	11.7
SmithKline Beckman	1,005.4	146.5	18	28	14.6	13.5
Squibb	470.4	69.4	22	51	14.8	11.9
Sterling Drug	492.1	41.6	17	14	8.5	8.7
Upjohn	597.4	80.9	11	28	13.5	11.7
Warner-Lambert	822.2	73.4	10	13	8.9	8.7
TOTAL	\$19,986.3	\$1847.6	11%	21%	13.2%	12.2%

^a After tax, excluding major nonrecurring and extraordinary items. ^b Earnings as a percentage of sales.

New Zealand conference focuses
on methane conversion Page 22
PRELIMINARY PROGRAM
ACS meeting in New Orleans Page 37

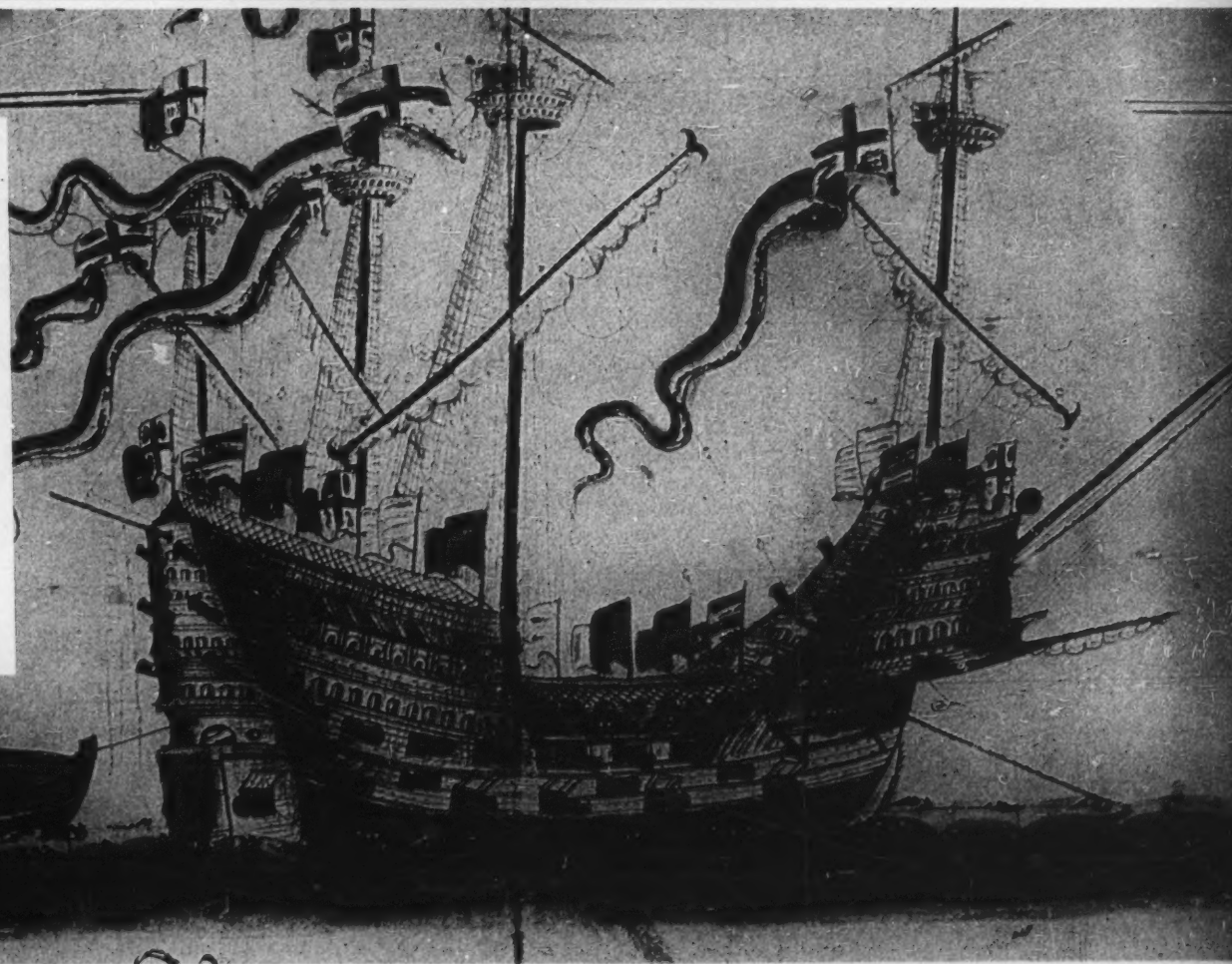
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Chemical Preservation

British attempt to conserve
16th-century vessel Mary Rose
Page 19

News of the Week

■ U.S.'s uranium enrichment enterprise must be restructured to become competitive, forum speakers conclude. **Page 4**

■ USDA should expand its biotech research programs, support at least 500 postdoctoral positions to retrain scientists to work in the field, NRC report recommends. **Page 5**

■ Arco will offer methanol/gas blend in 25 of its service stations in southern California. **Page 5**

■ Studies of data to explain loss of stratospheric ozone, collected in last year's Antarctica expedition, yield only more questions. **Page 6**

■ The 47 chemical laboratories chosen for a study to determine the quality of drug testing had a 99.2% accuracy rate. **Page 6**

Business

U.K.'s Courtaulds is moving away from its dependence on textiles to emphasize chemicals, materials, other areas to ensure growth. **Page 9**

Degussa, preparing to start up a hydrogen peroxide plant in Mobile, is bullish on the chemical and its many uses. **Page 14**

Government

Amendment to delete funds for the final assembly of binary chemical artillery shells defeated by the House. **Page 16**

Office of Technology Assessment warns that waste dumping into coastal waters is degrading water quality and causing human health problems, suggests remedies. **Page 17**

Technology

Economical processes to convert methane directly to fuels, chemicals discussed at international symposium in New Zealand. **Page 22**

ACS News

Official reports of the ACS Board and Council meetings held in Denver include committee reports. **Page 29**

Preliminary Program

Preliminary program for ACS national meeting in New Orleans lists all symposia, includes preregistration forms. **Page 37**

Cover: Photo courtesy of Mary Rose Trust

Letters **2**

Concentrates

Business **7**

Government **15**

Science/Technology **18**

The Departments

Meetings **51**

Newsbriefs **64**



Cover Story

The Mary Rose, a 16th century ship raised from the English Channel in 1982, undergoes preservation using a combination of glycols. **Page 19**

Degussa sees growing hydrogen peroxide use

Degussa Corp. has opened peroxygen chemicals laboratories at its technical center in Allendale, N.J., at a time when the company is preparing to start up an 80 million lb-per-year hydrogen peroxide plant in Mobile, Ala., in June. The laboratories will do the applications research that the company needs to expand U.S. hydrogen peroxide markets more than 10% annually from 365 million lb in 1987 to at least 590 million lb in 1992.

In addition to present applications in chemicals, pulp and paper, textiles, the environment, mining, and electronics, Degussa will find additional opportunities in cyanide destruction in precious metals refining, delignification of agricultural wastes, poultry processing, and pretreatment of wastes and supplemental oxygen supply for biological degradation, predicts marketing director Rudi Moerck. Moerck cites these domestic uses, plus expected exports, as spurs to growth as high as 15% per year.

Among other producers, Du Pont brought on an 80 million lb-per-year expansion of its Memphis hydrogen peroxide plant in January. FMC has capacities of 95 million lb per year in Bayport, Tex., and 85 million lb in South Charleston, W.Va. The Deer Park, Tex., plant of

U.S. hydrogen peroxide sales to hit 365 million lb

Application	1987 consumption (millions of lb)
Chemical production	80
Pulp & paper	80
Textiles	45
Environmental	70
Mining	10
Electronics	10
Other	55
Subtotal	350
Exports	15
TOTAL	365

Interox is rated at 110 million lb per year. And Oxychem will start up a 45 million lb-per-year Canadian plant in the fourth quarter that will supply the whole North American market.

Even so, Moerck gives two reasons that the industry will sell 90% or more of effective hydrogen peroxide capacity for the next several years. First, he says, though all these startups add up to a 1987 nameplate capacity of 620 million lb, prorated capabilities of new plants will result in a nameplate figure of only 505 million lb for this year. In addition, he cautions that operating rates of hydrogen peroxide plants are really only 80% of nameplate.

Degussa's continuous process for cyanide destruction is the brainchild of mining technology manager Andrew Griffiths. A small stream of water from cyanide leaching of gold is drawn off for passage through an analysis chamber. Addition of sodium persulfate oxidizes cyanide to cyanate, and monitoring of the chamber pH and redox potential affords a steady-state titration of peroxygen needs of the stream.

Data from these measurements allow automatic setting of hydrogen peroxide addition and residence time in the main reaction chamber by a process controller. This results in complete destruction of cyanide with use of minimum hydrogen peroxide.

In the main chamber, hydrogen peroxide oxidizes cyanide to cyanate, which in turn hydrolyzes to ammonium carbonate. Also oxidized

is cyanide in labile complexes of cadmium, copper, and zinc, which precipitate as hydroxides at high pH. Ferrocyanide is precipitated as the copper salt. Excess copper from this step is precipitated by trimercaptotriazine, also a Degussa product. The net result is reduction of cyanide to less than 1 ppm.

Degussa has designed a lab module to contain the analysis chamber and process controller. The module has the dimensions of a freight container, so it can be shipped to remote mining areas. For example, the company has operated such a module at a site in Papua New Guinea.

Among newer environmental uses of hydrogen peroxide, the compound may aid in microbial destruction of such substances as gasoline leaking from underground storage tanks. Injected into soil at concentrations nontoxic to soil bacteria, hydrogen peroxide can break down there to oxygen and water. The released oxygen could enhance aerobic degradation of organics that threaten to contaminate groundwater.

In poultry processing, hydrogen peroxide might find applications to treat chilled water used for multiple washings of carcasses after slaughter and dressing of birds. Wash waters contain fats and other substances from carcasses, and oxidation of these could ease recycling of these waters. Careful analyses of peroxygen needs and resulting controlled dosages would avoid both costs of excessive use and contact of hydrogen peroxide with carcasses.

Further in the future, marketing director Moerck suggests that hydrogen peroxide might be added to chilling baths where carcasses are kept before cutting into parts. This would destroy salmonella bacteria that might have gotten into chiller water by this point. Moerck notes that hydrogen peroxide would then be in contact with carcasses, however, and addition to chiller waters would thus need Food & Drug Administration approval.

Elsewhere in agriculture, Moerck foresees possible uses of hydrogen peroxide to delignify stalks from grain harvesting. This would convert such wastes into more usable cellulosic products.

Stephen Stinson, New York



Griffiths (left), two Degussa scientists check one of their mobile mining labs

JUNE 8, 1987

CHEMICAL & ENGINEERING

NEWS

Facts & Figures
for the chemical
industry
Page 24

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News of the Week

■ At international conference on AIDS, reports ranged from dire predictions of worldwide epidemic to cautiously optimistic results of new treatments. **Page 6**

■ An Administration policy on AIDS control and prevention began to take shape last week with proposals, some controversial, for testing certain groups; Congress took steps to promote education about the disease. **Page 7**

■ The Sterling Group offers to buy two polyester facilities owned by Celanese Fibers division of Hoechst Celanese. **Page 7**

■ FDA panel's recommendation to deny Genentech's request to approve blood clot-dissolving protein TPA until more data were provided had a negative effect on all biotech industry stocks. **Page 8**

■ Administration feud over policies to control ozone-depleting chlorofluorocarbons comes to light when Interior Secretary's remarks are leaked to the press. **Page 8**

Letters	4
Concentrates	
Business	9
Government	12
Science/Technology	16
The Departments	
New Products	84
Meetings	87
Newsclips	106

Business

Most leading biotechnology firms show gains in first-quarter revenues and narrowing losses. **Page 11**

Government

NSF reports on Japan's goals for science and technology note emphasis on an environmental, humanistic approach. **Page 13**

Science

The structures of calicheamicins and esperamicins, potent new classes of anticancer agents, have been determined. **Page 17**

The Soviet Union has begun a long-term study of the health of those who were closest to the Chernobyl reactor when it exploded. **Page 19**

Technology

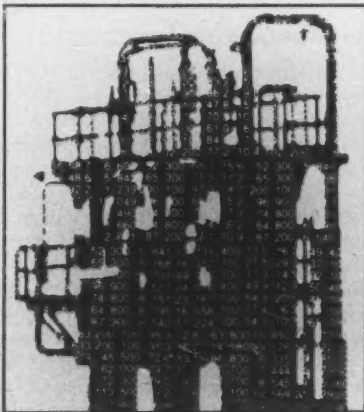
Search for catalytic methods to convert methane to fuel includes, among others, use of heteropoly oxometalates. **Page 20**

Books

"Chemicals and Society: A Guide to the New Chemical Age" does what chemists have failed to do—communicate with the layperson. **Page 77**

ACS News

Petroleum Research Fund grants approved by ACS Board of Directors add \$3,468,264 to 1987 funding. **Page 80**



Facts & Figures

The U.S. chemical industry witnessed a steady, but slow, growth in 1986; however, cost-cutting measures of the past few years led to higher earnings. C&EN's annual survey of the industry in the U.S. and abroad gives the latest trends. **Page 24**

Losses Narrow at Most Biotechnology Firms

Revenues increased sharply and, in most instances, losses narrowed at leading biotechnology companies in the first quarter of this year. At some firms, the rise in revenues came from improved product sales, but at others, bigger and more collaborative research agreements are responsible. For many of the 18 companies surveyed by C&EN, this increase in revenues translated in the bottom line to narrow losses and, for several, provided profits.

For the 18 biotechnology companies, revenues in the first quarter increased an average 34% from last year's first quarter to a cumulative \$111 million. At the same time, total losses for the entire group rose to \$15.3 million from \$12.1 million in first-quarter 1986. However, losses at troubled Monoclonal Antibodies were larger than the increase in the cumulative loss. The company lost more than \$5.4 million in the first quarter, compared with profits of \$181,000 in the same period last year.

Excluding Monoclonal Antibodies, the cumulative loss for the group was about \$9.9 million, down from \$12.2 million in first-quarter 1986.

For the four companies reporting products sales, these rose to a total of \$12.5 million, an increase of 51% over the same quarter last year. Perhaps the most important of the four from a financial standpoint was Calgene, whose product sales climbed from zero in what was its second fiscal quarter of 1986 to almost \$5 million in the first quarter this year. However, the reason for this rise was not a biotechnology product, but rather sales of cottonseed through Calgene's recently acquired Stoneville Pedigreed Seed Co. subsidiary.

This, along with new product development agreements with Nippon Steel and Procter & Gamble, contributed to the company's first profitable quarter. Calgene's chief financial officer Daniel O. Wagster cautions that the firm's quarterly financial performance now will be

affected by the seasonality of the cottonseed subsidiary Stoneville, which is expected to operate at a profit in the company's second and third fiscal quarters and at a loss in the first and fourth quarters. Calgene recorded a profit of \$493,000 in the quarter, compared with a loss of \$304,000 in the same period last year.

At other companies with product sales, Genentech registered an increase of 126% to \$16.5 million and Cetus sales were up 66% to \$730,000. Product sales of Molecular Genetics, however, fell 48% to \$267,733. According to Molecular Genetics, unit sales volume of Genecol 99 monoclonal antibody for the prevention of calf deaths from *Escherichia coli* scours did not meet expectations because of production difficulties in gearing up manufacturing to build inventory.

Of the 18 companies surveyed, five registered earnings in the first quarter. Amgen had a profit of \$232,000, up 13% from the year-earlier quarter; Calgene had earnings of \$493,000, compared with a loss in first-quarter 1986; Centocor had earnings of \$2.82 million, up 76% from the same quarter in 1986; Genentech had an 84% gain to \$3.23 million; and Synergen had earnings of \$81,000, down 73% from first-quarter 1986.

The continuing deficits of some companies generally were explained as the result of decisions to invest money for the future. Comments by Gabriel Schmergel, president and chief executive officer of Genetics Institute, which lost \$1.31 million in the quarter, were typical: "The losses reflect Genetics Institute's strategic decision to invest prudent levels of equity in the development of products that we can manufacture and bring to market. We will continue to follow this financing strategy until meaningful revenues commence from commercialization of products now in clinical testing."

William Storck, New York

Revenues up at most biotechnology firms

	FIRST-QUARTER 1987					
	Revenue (\$ millions)	Earnings	Change from 1986		Profit margin ^a	
			Sales	Earnings	1987	1986
Amgen	\$10.026	\$0.232	55%	13%	2.2%	3.0%
Biogen	3.965	-5.589	4	def	def	def
BioTechnica International	1.592	-1.964	-11	def	def	def
Calgene	7.353	0.493	508	def	6.7	def
California Biotechnology	3.014	-1.583	-7	def	def	def
Centocor	11.952	2.815	64	76	23.6	21.9
Cetus	13.603	-0.946	-9	def	def	2.4
Cytogen	2.618	-0.280	864	def	def	def
Damon Biotech	1.243	-2.162	49	def	def	def
DNA Plant Technology	1.805	-0.085	76	def	def	def
Genentech	38.606	3.231	33	84	8.4	6.0
Genetics Institute	5.271	-1.309	19	def	def	def
Immunex	3.500	-0.311	169	def	def	def
Liposome	0.872	-1.491	41	def	def	def
Molecular Genetics	1.251	-0.907	-15	def	def	0.8
Monoclonal Antibodies	1.553	-5.430	-39	def	def	7.1
Ribi ImmunoChem	0.430	-0.133	9	def	def	9.1
Synergen	2.256	0.081	1	-73	3.6	13.5

^a Net earnings as a percentage of revenues. def = deficit.

NSF Profiles Japan's Science and Technology Strategy

National Science Foundation reports reflect emphasis by Japan on social, humanistic approach to science and its translation into policy

Will Lepkowlak, C&EN Washington

For the past five years, the National Science Foundation's Tokyo office has been turning out a series of intelligence reports on science and technology trends of America's number one competitor, Japan. Taken together, the reports present a unique running profile of how Japan has changed its strategies to gear its technical machine to the Japanese idea of progress.

Some of the more current reports describe issues such as competition between Japan's two major technical agencies, trends in Japanese financial support of U.S. academic and industrial research, the country's new stress on science and technology to meet mankind's needs, and a directory of selected Japanese scientific research institutes.

Until early this year, the reports were produced more or less for the in-house consumption of NSF. But in January the foundation established a new division of information and analysis with the eventual aim of developing ways of monitoring technical highlights in all the major areas of the world and marketing the results.

The Japanese reports are compiled by a four-person NSF staff in Tokyo headed by Alexander P. DeAngelis. One of the more fascinating of the Japanese reports, memorandum 115, was issued last December describing Japan's 1986 White Paper on Science & Technology.

The current document, issued by Japan's Science & Technology Agency (STA), has the theme "Toward a Better Environment for Man." Essentially, it provides a technology assessment of Japan as a whole through the mid-1980s and describes its vision of the future. Last year the theme was "New Development for R&D and the Era of Cooperation."

Inspiring the theme, according to NSF, is Japan's concern over the "good and evil" effects of technology on people's lives. The evil effects, it says, "are invasion of privacy through electronic means, separation of the individual from the community, spoiling of the natural environment, and the growing gap between increasing reliance on technology and decreasing ability to understand it."

The Japanese appear to be emphasizing the social and humanistic approach by promoting the coming need for "human friendly" science and technology alongside their policy of strengthening basic research. How that is translated into policy and, further, into international commercial markets should be one of the more intriguing questions for today's Japan watchers.

Human beings, the paper says, "have become increasingly aware of the benefits of advancing science and technology in the form of improved medical care, high-tech products, and [better] clothing, food, and shelter. On the other hand, they have begun to realize the drawbacks attendant upon such development, for example, the decline of skill as the price of convenience, and the depersonalization of human relations through mechanization."

So, the paper asks: "What is the level of well-being and the sense of fulfillment people seek in human terms? Although well-being and ful-

fillment can be achieved through various economic, social, and cultural activities, what are the roles science and technology can play in helping the people achieve these aims?" Some of those questions lay behind a program begun last year by another major Japanese agency, the Ministry of International Trade & Industry. MITI's program, called the "Human Frontier Program," is seen by NSF to be somewhat competitive with STA's "human friendly" enterprise and is aimed at supporting research around the world in "ecology friendly" technology.

Japan says advanced technology today seems to be headed in three separate directions: first, toward increased development of new inorganic materials through research at the molecular level and of new pro-

Japanese science and technology at a glance

Total R&D spending: \$59.3 billion in fiscal 1986, ended March 31, 1987 (\$1.00 = 150 yen in 1987), up 13% from previous fiscal year

Sources: National and local governments, 21%; private sector, 79%

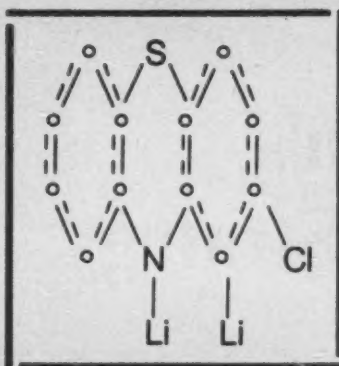
Ratio to gross national product: 2.8%

Total full-time researchers: 474,000. Breakdown by place of work: private industry, 252,000; research institutes, 37,000; universities, 185,000

Expenditure per researcher: \$144,667. Breakdown by place of work: research institutes, \$212,000; private industry, \$157,333; universities, \$64,667

Payment/receipt ratio in international technology trade: 1.25 (\$1.95 billion vs. \$1.56 billion). 0.35 for transactions initiated only in fiscal 1985

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teins with broad health and agricultural applications. Second, toward integrated-systems approaches to solving most technical problems, from R&D decision making to medical treatment. Third, toward increased bioelectronic technology to enhance and replace body functions.

What all that means, according to today's Japanese futurists, is intensified development of products that "directly touch people's lives." One example is "technologies aimed at enhancing the human sensory mechanisms by the application of high technology, such as computer graphics and holography. In addition, technologies highly responsive to man's psychological and ecological needs are expected to develop in the coming years." What is so fascinating about Japan's science policy language is its contrast to the rhetoric of the U.S. technical establishment with its generalized focus on engineering and competitiveness without much specific reference to human and ecological values.

To take advantage of these trends, the report says that youth must be trained differently. It suggests exposing them to science at increasingly early ages and infusing in them attitudes "receptive to learning from the mechanisms and the working systems of nature and human beings." Thus, "greater efforts to help rear nature-loving and emotionally balanced youngsters will power the development of human-friendly science and technology."

Alongside Japan's vision of the goals for science and technology is its strategy toward international cooperation in technical fields. This policy is embodied in MITI's "Human Frontier Program." But because that program, according to NSF, has been somewhat competitive with STA's Human & Earth Sciences Program, Japan is not speaking with a single policy voice.

Premier Yasuhiro Nakasone was supposed to have proposed an international cooperation plan before the May 1986 summit meeting in Tokyo, but changed his mind when the two agencies couldn't coordinate their proposals. NSF analysts believe that Nakasone could resurrect the proposal during this week's summit meeting in Venice.

In any case, the human frontier initiative does represent a "new paradigm" in technological thinking, according to the NSF analysis, in that it claims that current technology has up to now been antagonistic to nature and needs to be made more harmonious with it. The Japanese thrust calls for "technology for utilizing the functions of living bodies." As NSF explains the terms, MITI "envision[s] not just another major [science and technology] program, but an actual redirection of technological development away from the prosperity-creating yet destructive physical-mechanical model to a biological model, which MITI hopes and believes will make [society] more a part of the natural order rather than its enemy."

In another paper, NSF attempts to analyze Japanese industrial support of research in American universities. NSF estimates that in 1986 Japanese companies spent about \$9.1 million for research at American universities. The amount is minuscule alongside the approximately \$10 billion U.S. academic basic research budget. But Japan has swiftly become the world's chief financial power with enormous investments in U.S. industry, banking, and real estate. That wealth is expected to spread to research, according to NSF. Moreover, American universities could begin soliciting such support. Massachusetts Institute of Technology already operates an office in Tokyo, and several other universities have followed suit. About a third of the Japanese companies obtain patent rights from the academic research they support in the U.S.

The NSF analysis concludes that Japanese spending in American universities is growing at a "prodigious" rate. "There is a consensus that more basic research will be needed for input to future industrial development than is available from Japanese [science and technology] resources. It is not surprising, therefore, that Japanese industry should include acquisition of basic research from abroad as part of its strategy to keep at the forefront of scientific and engineering knowledge."

NSF adds that Japanese companies are establishing their own research facilities in the U.S. As of

last fall, 22 had such facilities, and 87 said they were making plans to do so. The trend likely will open up significant employment opportunities for U.S. scientists and engineers, says NSF.

Owens says the U.S. presence in Japan, in the form of technical staff from American industry and academia, remains small—"in the hundreds"—and that the American professionals remain at a disadvantage in their lack of proficiency in the Japanese language.

The "character" of Japanese science and technology policy reflects a "strong moral force" operating in the country as it moves into an intensified area of basic research and human applications. It takes two directions. "If you look at the changes in policy with respect to supporting basic research," Owens says, "you see two elements. One reflects a fear that if the Japanese don't do more research in-house the world may cut them off from new knowledge. The other half of that says Japan is an economically important country and that it behooves it to act responsibly toward the rest of the world in terms of initiating ideas instead of only borrowing them."

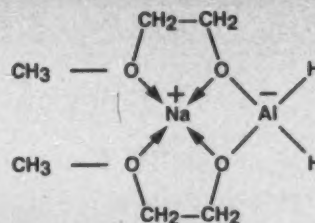
Owens is concerned with some U.S. policy tendencies toward restricting the flow of research to Japan. "I think it's a mistake to mix trade matters with those of science and technology," he says. "If we cut off what we share with them, they can cut off what we get. This kind of thinking never gets into trade discussions."

So far, 117 reports on Japan have been produced by NSF's office. Those in the pipeline include a list of new categories of grants in priority areas of research, a description of newly established joint industry-university research centers, and a rundown of superconductivity research being performed at one of the major laboratories funded by STA.

Owens is hoping the reports will be made more widely available to U.S. industry and universities. A pilot program with the State and Commerce departments will be under way shortly to explore ways of including the NSF reports in their public distribution networks. □

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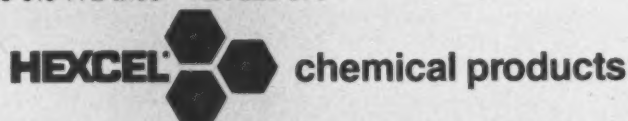
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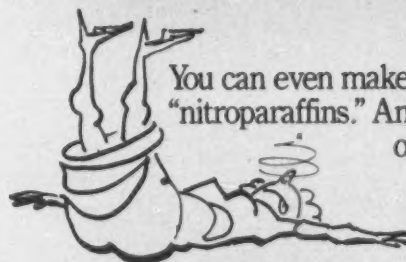
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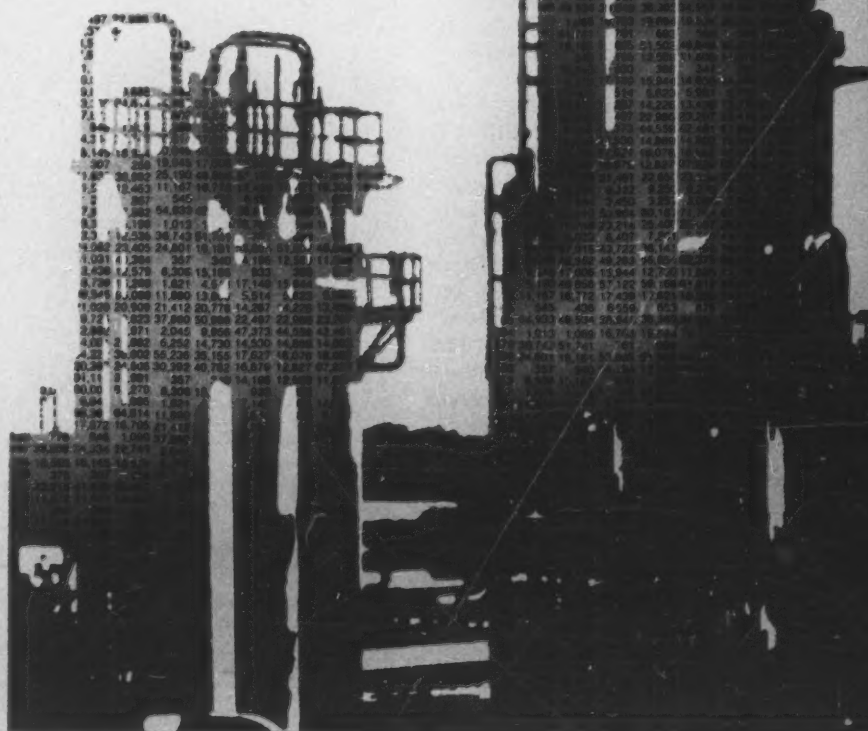
for the chemical industry

Much like the year before, 1986 was a period of steady but rather weak growth for the U.S. chemical industry. Output was up 5%, but that overall figure masks a mixture of favorable growth for such products as organic chemicals and plastics with more disappointing results for synthetic fibers and, especially, agricultural chemicals.

Where last year did differ markedly from 1985 is on the bottom line of chemical companies' profit-and-loss statements. The drastic cost-cutting measures of the past few years, which had impinged especially heavily on 1985's financial record, paid off handsomely in higher earnings and sturdier balance sheets for many companies in 1986.

These developments are depicted statistically in the data published on the following pages of C&EN's annual Facts & Figures issue. They detail the recent performance of the chemical industry in the U.S. and, to a lesser degree, in several major chemical-producing countries abroad. These data have been collected from a wide variety of sources, including government agencies, trade associations, and international organizations, as well as from the companies themselves that make up the chemical industry. C&EN itself has,

in many instances, used the basic statistics to develop analytical measures and comparisons that add broader perspective to the industry's recent record.



at a glance

Section One: Production

Production of chemicals in the U.S. continued to rise last year, as it has every year since 1982. And although, overall, the growth was relatively modest, it was considerably greater than that for all U.S. industry. For basic chemicals, the year was pretty much of a standoff, with organic chemicals up but many inorganics weak, largely as a result of poor demand for materials aimed at the depressed farm market. Plastics had a good year, but synthetic fibers were lackluster as low-cost imports continued to plague the textile industry.

Page 26

Section Two: Finance

Although sales were only slightly higher than the year before, chemical companies' streamlining efforts of the past two or three years finally bore fruit, as profits for many firms rebounded strongly in 1986. The industry remains very cost conscious, nonetheless; capital spending, for example, continues to be held in rein, and R&D budgets, although still expanding, are not doing so at so fast a rate as previously.

Page 35

Section Three: Employment

The number of workers employed by chemical companies has been on a downtrend since the end of 1984 that has carried it to the lowest level in more than a decade. But with output a bit higher, a smaller work force means that productivity in the industry has been improving and unit labor costs are lower.

Page 58

Section Four: Foreign Trade

Thanks largely to the weakness of the U.S. dollar, the U.S. trade surplus in chemicals expanded a bit last year following five years of steady decline. Total world trade in chemicals was higher last year, too, though not nearly so much as the dollar figures might suggest.

Page 61

Section Five:

Foreign Chemical Industries

Although growth in output of many major chemicals faltered in 1986, profitability generally was higher among the major producers both in West Europe and Canada. In Japan, however, not only did production of most large-volume chemicals slump but earnings of the largest chemical companies also were well below those of the year before.

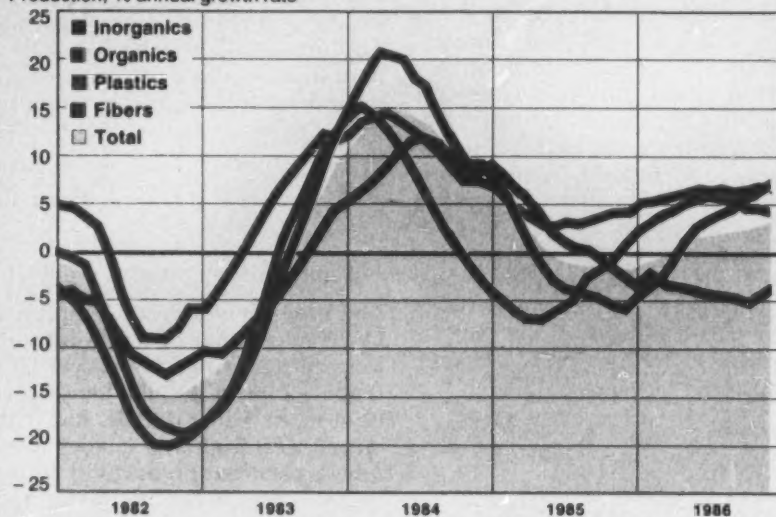
Page 63

1 Production by the U.S. Chemical Industry

Moderate growth continues for another year

Chemical growth rates held relatively stable during 1986

Production, % annual growth rate^a



^a Average running annual growth rates in production of major plastics, inorganic and organic chemicals, and all chemicals, and in shipments of man-made fibers. Sources: International Trade Commission, Bureau of the Census, Society of the Plastics Industry, Textile Economics Bureau

Output of U.S. chemical plants was 5% higher last year than in 1985. That performance for chemicals was much better than industry did as a whole, however; total industrial production was up only 1%. And in the first half of 1987, the chemical industry appears to be maintaining the slow but steady growth it sustained throughout 1986.

Plastic materials again were among the strongest sectors of the chemical industry, with output rising for the fourth straight year. Production of thermoplastic resins increased 7%, led by a 22% increase in output of thermoplastic polyester. Nylon, polypropylene, and polystyrene also posted large gains. Among thermosets, output of epoxy, polyester, urea, and phenolic resins grew a little in 1986, but melamine output dropped off for the second straight year.

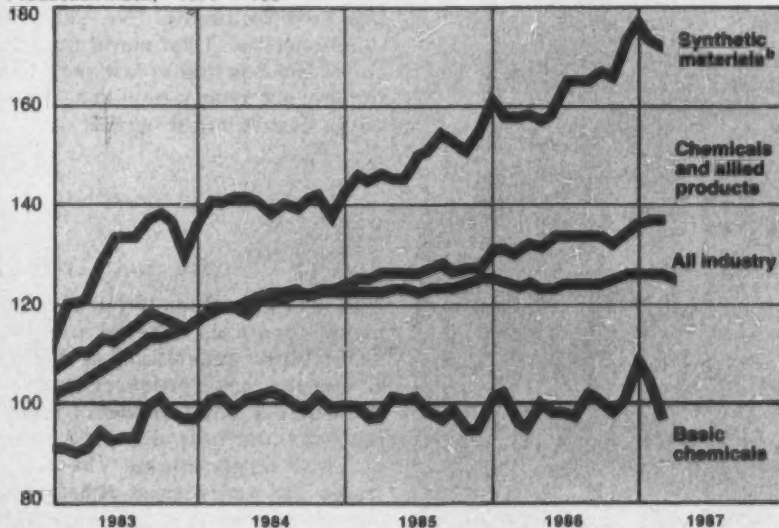
Man-made fibers production increased sluggishly in 1986. Nylon and olefin fibers outperformed the other noncellulosics, while production of acetate and rayon rebounded 11% after having slumped in 1985.

Output of basic chemicals was up only 1% in 1986 from a year earlier. Organic chemicals, industrial gases, and inorganic pigments grew moderately, but the sector as a whole was dragged down by steep drops in production of fertilizer materials. Production of fertilizers themselves was off close to 20%, compared with 1985. Financial problems on U.S. farms have caused a sharp drop in demand for agricultural chemicals of all types, and export markets also have been weak despite the decline in the value of the U.S. dollar.

The chemically related products sector raised output 6% in 1986, about the same as for the chemical industry as a whole. Production of soap and toiletries was up 11%, that of drugs up 5%, and paint production increased only 1% over the previous year.

Chemical output has edged higher in the past year

Production index, ^a 1977 = 100



^a Seasonally adjusted. ^b Includes plastics, synthetic rubber, and man-made fibers. Source: Federal Reserve Board

TOP 50 CHEMICALS: Rebound in organic chemical output balances slump for inorganics

Rank			Billions of lb		Common units ^a		Average annual growth			
1986	1985 ^a		1986	1985	1986	1985	1985-90	1984-85	1981-80	1978-80
1	1	Sulfuric acid	73.64	79.30	36,822 tt	39,651 tt	-7.1%	-5.1%	-2.0%	0.5%
2	2	Nitrogen	48.62	47.46	671 bcf	655 bcf	2.4	-0.9	6.5	8.8
3	4	Oxygen	33.03	32.53	399 bcf	393 bcf	1.5	2.1	-1.5	0.4
4	6	Ethylene	32.81	29.85	32,811 mp	29,847 mp	9.9	-4.9	2.2	3.9
5	5	Lime ^c	30.34	31.60	15,172 tt	15,800 tt	-4.0	-1.2	-4.3	-2.3
6	3	Ammonia	28.01	34.64	14,005 tt	17,319 tt	-19.1	3.8	-6.0	-1.8
7	7	Sodium hydroxide	22.01	21.79	11,007 tt	10,893 tt	1.0	-0.2	1.1	0.5
8	9	Chlorine	20.98	20.79	10,489 tt	10,395 tt	0.9	-2.8	-0.5	0.1
9	8	Phosphoric acid	18.41	21.04	9,206 tt	10,518 tt	-12.5	-7.5	-1.6	1.5
10	11	Propylene	17.34	14.89	17,343 mp	14,887 mp	16.5	-4.3	5.2	5.6
11	10	Sodium carbonate ^d	17.20	17.19	8,600 tt	8,597 tt	0.0	1.0	0.8	5.1
12	15	Ethylene dichloride	14.53	12.10	14,529 mp	12,101 mp	20.1	13.0	7.8	6.1
13	12	Nitric acid	13.12	14.73	6,562 tt	7,364 tt	-10.9	-4.7	-6.3	-1.7
14	14	Urea ^e	12.06	13.36	6,029 tt	6,678 tt	-9.7	-10.2	-5.6	4.4
15	13	Ammonium nitrate ^f	11.11	13.55	5,556 tt	6,776 tt	-18.0	-5.2	-8.9	-2.5
16	17	Benzene	10.23	9.39	1,389 mg	1,275 mg	8.9	-3.3	1.2	-0.3
17	20	Ethylbenzene	8.92	7.39	8,915 mp	7,386 mp	20.7	-2.3	2.7	4.4
18	18	Carbon dioxide ^g	8.50	9.25	4,252 tt	4,623 tt	-8.0	1.3	2.3	8.0
19	16	Vinyl chloride	8.42	9.46	8,415 mp	9,463 mp	-11.1	55.5	4.1	4.0
20	19	Styrene	7.84	7.62	7,838 mp	7,622 mp	2.8	-1.1	3.3	2.2
21	21	Terephthalic acid ^h	7.68	6.49	7,684 mp	6,490 mp	18.4	9.8	4.3	0.6
22	27	Methanol	7.33	5.00	7,327 mp	5,003 mp	46.5	-38.9	-3.1	1.6
23	22	Hydrochloric acid	5.97	5.61	2,983 tt	2,807 tt	6.3	2.7	3.0	1.6
24	24	Ethylene oxide	5.94	5.43	5,943 mp	5,430 mp	9.4	-4.7	2.9	3.6
25	22	Formaldehyde ⁱ	5.89	5.61	5,885 mp	5,606 mp	5.0	-3.6	0.6	0.8
26	26	Toluene ^j	5.82	5.07	802 mg	699 mg	14.7	-4.0	-1.2	-2.2
27	25	Xylene	5.55	5.31	771 mg	738 mg	4.5	-13.6	-2.6	0.7
28	30	Ethylene glycol	4.76	4.18	4,759 mp	4,178 mp	13.9	-13.4	2.8	3.6
29	28	p-Xylene	4.67	4.78	4,669 mp	4,779 mp	-2.3	12.1	0.6	4.8
30	29	Ammonium sulfate	4.17	4.19	2,086 tt	2,093 tt	-0.3	1.3	-0.9	0.4
31	31	Cumene	3.70	3.35	3,695 mp	3,345 mp	10.5	-10.9	2.2	3.1
32	32	Acetic acid	2.93	2.90	2,931 mp	2,897 mp	1.2	10.6	-0.9	1.8
33	34	Phenol ^k	2.92	2.78	2,921 mp	2,777 mp	5.2	-3.9	2.5	3.3
34	39	Butadiene ^l	2.59	2.34	2,593 mp	2,340 mp	10.8	-4.6	-2.8	-3.0
34	35	Carbon black	2.59	2.57	2,585 mp	2,571 mp	0.5	-11.1	-1.1	-1.6
36	33	Potash ^m	2.58	2.84	1,169 tmt	1,288 tmt	-9.2	-17.6	-11.5	-6.0
37	36	Aluminum sulfate	2.52	2.54	1,256 tt	1,268 tt	-0.8	12.3	-0.6	0.5
38	37	Propylene oxide	2.48	2.40	2,480 mp	2,400 mp	3.3	34.9	6.1	3.1
39	38	Acrylonitrile	2.31	2.35	2,314 mp	2,346 mp	-1.4	5.7	3.0	4.3
40	40	Vinyl acetate	2.25	2.11	2,249 mp	2,112 mp	6.5	4.3	3.0	4.3
41	41	Methyl tert-butyl ether ⁿ	2.24	1.89	2,237 mp	1,891 mp	18.3	37.4	24.1	nm
42	44	Cyclohexane	2.07	1.66	2,071 mp	1,657 mp	25.0	-16.9	2.6	-0.5
43	42	Acetone	1.94	1.79	1,936 mp	1,788 mp	8.3	-4.0	-2.0	0.4
44	43	Titanium dioxide	1.83	1.72	917 tt	860 tt	6.6	3.0	3.8	2.5
45	48	Sodium silicate	1.57	1.44	786 tt	721 tt	9.0	-3.9	0.4	0.5
46	46	Calcium chloride ^o	1.56	1.88	780 tt	940 tt	-17.0	-10.4	-3.2	-4.2
47	45	Sodium sulfate ^p	1.55	1.65	775 tt	827 tt	-6.3	-5.2	-6.9	-4.5
48	47	Adipic acid	1.52	1.45	1,522 mp	1,453 mp	4.7	4.5	2.0	0.0
49	50	Isopropyl alcohol	1.28	1.24	1,275 mp	1,235 mp	3.2	-11.4	-5.2	-4.1
50	49	Sodium tripolyphosphate	1.27	1.25	634 tt	625 tt	1.4	-7.4	-1.8	-1.3
TOTAL ORGANICS			188.00	172.16			9.2%	-1.9%	1.8%	2.9%
TOTAL INORGANICS			350.60	369.56			-5.1%	-2.0%	-1.5%	0.8%
GRAND TOTAL			538.60	541.72			-0.6%	-2.0%	-0.5%	1.5%

a Revised. b tt = thousands of tons, bcf = billions of cubic feet, mp = millions of pounds, mg = millions of gallons, tmt = thousands of metric tons. c Except refractory dolomite. d Natural and synthetic. e 100% basis. f Original solution. g Liquid and solid only. h Includes both acid and ester without double counting. i 37% by weight. j All grades. k Synthetic only. l Rubber grade. m K₂O basis. n Production data for earlier years unavailable. o Solid and liquid. p High and low purity. nm = not meaningful.

1 Production by the U.S. Chemical Industry

PRODUCTION: Chemical industry as a whole shows modest growth

Industrial production indexes, 1977 = 100	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	Annual change	
												1985-86	1976-86
Total index	125.1	123.8	121.4	109.2	103.1	111.0	108.6	110.7	106.5	100.0	92.6	1%	3%
Manufacturing, total	129.1	126.4	123.4	110.2	102.2	110.5	108.2	111.5	107.1	100.0	91.9	2	3
Nondurable manufacturing	130.9	125.1	122.3	113.7	105.5	109.7	107.0	108.2	105.5	100.0	93.1	5	3
Chemicals and products	133.0	127.1	121.6	114.0	103.8	112.6	108.4	111.4	106.8	100.0	92.8	5	4
Chemicals and synthetic materials	123.3	117.7	114.7	109.1	95.4	109.4	99.4	113.7	108.2	100.0	90.0	5	3
Basic chemicals	99.5	98.8	100.6	95.0	90.6	104.3	107.2	110.1	110.7	100.0	94.8	1	0
Alkalies and chlorine	97.5	97.2	97.8	91.5	83.3	96.1	104.1	113.6	101.7	100.0	109.9	0	-1
Industrial gases	131.8	120.3	123.6	114.0	103.9	115.4	105.0	107.2	98.7	100.0	84.3	10	5
Inorganic pigments	100.6	91.8	95.4	91.5	81.7	99.0	97.6	100.8	103.5	100.0	109.2	10	-1
Inorganic chemicals, nec	94.3	96.4	97.9	92.9	90.9	104.6	109.4	111.1	115.3	100.0	92.4	-2	0
Industrial organic chemicals	111.2	107.9	106.2	104.0	90.3	105.5	89.1	108.1	104.5	100.0	88.5	3	2
Synthetic materials	163.1	149.4	140.3	129.0	108.0	120.2	110.1	125.8	112.2	100.0	89.2	9	6
Plastics materials	220.9	197.4	179.8	158.7	129.9	136.1	122.1	132.6	115.6	100.0	86.7	12	10
Synthetic rubber	96.5	96.8	107.6	98.3	86.8	91.2	93.0	112.1	99.0	100.0	98.9	0	0
Man-made fibers	98.5	95.3	94.1	95.4	82.9	104.6	97.3	119.4	110.2	100.0	89.8	3	1
Chemical products	150.1	141.7	132.4	123.2	114.7	116.5	113.7	110.1	106.7	100.0	95.4	6	5
Drugs and medicines	135.3	129.0	121.7	118.8	114.2	112.0	112.9	107.5	105.1	100.0	95.9	5	4
Soap and toiletries	188.7	170.4	155.9	139.9	125.4	129.6	121.5	115.0	106.6	100.0	96.3	11	7
Paints	100.3	99.5	92.9	90.1	83.5	86.7	89.7	95.0	104.7	100.0	94.8	1	1
Agricultural chemicals	85.6	96.1	98.2	86.9	90.2	109.2	107.3	103.9	97.5	100.0	92.5	-11	-1
Petroleum products	92.1	86.8	87.4	84.0	84.2	89.4	94.0	101.7	102.5	100.0	92.8	6	0
Rubber and plastics products	153.4	146.9	143.5	124.3	110.2	116.4	107.8	114.9	107.5	100.0	84.9	4	6

nec = not elsewhere classified. Source: Federal Reserve Board

MINERALS: Operations were down again in 1986, continuing a long-term trend

Thousands of tons	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	Annual change	
												1985-86	1976-86
Bromine, sold or used^a	163 ^b	160	193	185	200	189	189	249	223	217	230	2%	-3%
Calcium chloride, production^{c,d}	780 ^b	940	1,036	912	853	917	811	981	1,031	968	897	-17	-1
Iodine, consumption^{e,f}	na	na	3.8 ^b	4.1	3.4	4.4	4.4	4.4	4.0	4.3	3.6	na	na
Imports ^f	1.5 ^b	2.7	2.6	3.1	2.3	3.0	3.1	3.1	3.4	3.5	3.2	-44	-7
Lime, sold or used^g	14,000 ^b	15,713	15,922	14,867	14,075	18,890	19,037	20,983	20,484	19,987	20,257	-11	-4
Lithium, consumption^{h,i}	2.4 ^b	2.5	3.2	2.2	2.0	3.2	3.0	3.2	3.4	4.1	2.8	-4	-2
Phosphate rock													
Marketable production	41,744	56,035	54,230	46,928	41,241	59,110	59,982	56,891	55,156	52,091	49,231	-26	-2
Exports	9,945	11,336	12,707	13,239	10,849	11,458	15,737	15,827	14,187	14,584	10,398	-12	0
Potash (K₂O equivalent)^j													
Production	1,213 ^b	1,429	1,724	1,575	1,967	2,377	2,468	2,453	2,484	2,457	2,400	-15	-7
Imports ^j	4,850 ^b	5,063	5,323	4,894	4,253	5,287	5,481	5,693	5,189	5,076	4,954	-4	0
Apparent consumption	5,527 ^b	5,893	6,838	6,231	5,647	6,849	6,999	7,826	6,840	6,605	6,149	-6	-1
Salt, total sold or used^k	36,800 ^b	39,464	39,225	34,573	37,894	38,915	40,396	45,820	42,896	43,439	44,218	-7	-2
Evaporated ^k	6,256 ^b	5,923	5,492	5,532	5,305	6,209	6,358	6,248	5,872	5,704	5,534	6	1
Rock ^k	13,616 ^b	13,819	13,337	12,446	12,884	11,871	11,806	14,891	14,688	14,958	15,668	-1	-1
Salt in brine ^k	16,928 ^b	19,742	20,397	16,595	19,705	20,835	22,231	24,681	22,336	22,777	22,917	-14	-3
Sodium carbonate, production^d	8,600 ^b	8,597	8,511	8,467	7,819	8,281	8,275	8,253	8,290	8,040	7,560	0	1
Sulfur, production^m	12,221	12,797	11,742	10,240	10,788	13,388	13,080	13,339	12,318	11,824	11,992	-4	0
Apparent consumption ⁿ	11,869	13,192	13,976	12,112	11,088	14,093	15,056	15,145	13,869	12,850	12,060	-12	0
Frasch, production	4,457	5,524	4,622	3,530	4,641	6,997	7,044	7,007	6,226	6,520	7,016	-19	-4
Recovered elemental, production	6,411	5,857	5,747	5,462	4,855	4,695	4,490	4,486	4,478	3,995	3,514	9	6
Other, production	1,354	1,416	1,372	1,249	1,293	1,695	1,547	1,845	1,615	1,310	1,462	-4	-1

a Elemental bromine sold as such or used in preparation of bromine compounds by primary producers. b Preliminary figure. c 75% CaCl₂ equivalent. d Natural and synthetic. e Estimated apparent consumption. f Crude elemental iodine. g Includes Puerto Rican production. h Lithium content basis. i Includes muriate and sulfate of potash, potassium magnesium sulfate, and parent salts; excludes other chemical compounds containing potassium. j Includes nitrate of potash. k Total obtained by all recovery methods that was sold or used by domestic producers (figures differ slightly from U.S. production figures); figures for 1973-81 include Puerto Rican production. l Sold or used as such. m Sulfur content basis. n Calculated from shipments plus imports minus exports (sulfur content basis). na = not available. Source: Bureau of Mines

1 Production by the U.S. Chemical Industry

ORGANIC CHEMICALS: Output last year generally increased—for some products sharply

Millions of lb unless otherwise noted	Production											Annual change	
	1986 ^a	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1985-86	1976-86
Acetic acid, synthetic	2,931	2,897	2,619	2,807	2,748	2,705	2,977	3,265	2,776	2,570	2,463	1%	2%
Acetone	1,936	1,788	1,862	1,859	1,694	2,144	2,076	2,653	2,519	2,219	1,869	8	0
Acrylonitrile	2,314	2,349	2,219	2,146	2,035	1,997	1,830	2,018	1,752	1,646	1,518	-1	4
Aniline	823	716	786	663	557	634	659	690	606	584	544	15	4
Benzene, mg ^{b,c}	1,395	1,283	1,318	1,232	1,052	1,308	1,534	1,612	1,435	1,371	1,365	9	0
Bisphenol A	823	949	762	643	480	555	530	576	471	455	449	-13	6
1,3-Butadiene ^d	2,646	2,340	2,452	2,353	1,915	2,986	2,799	3,583	3,515	3,259	3,507	13	-3
1-Butanol	868	716	908	833	730	809	790	766	756	660	625	21	3
Caprolactam	1,104	1,089	1,027	977	793	928	905 ^a	945	919	867	780	1	4
Carbon tetrachloride	625	646	713	573	587	726	710	714	737	809	857	-3	-3
Chloroform	422	275	405	362	299	405	273	356	349	302	292	53	4
Cumene	3,695	2,627	3,754	3,345	2,743	3,309	3,459	3,917	3,380	2,644	2,716	41	3
Cyclohexane	2,071	1,657	1,994	1,656	1,275	1,820	1,964	2,425	2,332	2,265	2,187	25	-1
Diethyl phthalate	290	275	301	300	266	304	353	336	409	400	413	5	-3
Dodecylbenzene ^e	na	547	561	545	509	535	563 ^f	627	526	526	529	na	na
Ethanol, synthetic	513	649	1,060	1,077	1,023	1,317	1,451	1,408	1,267	1,339	1,496	-21	-10
Ethanolamines ^g	549	537	504	468	416	429	376	420	362	308	286	2	7
Ethylbenzene	8,938	7,386	7,562	7,876	6,856	7,813	7,642	8,448	8,385	8,312	5,770	21	4
Ethyl chloride	160	171	290	282	339	324	396	582	540	612	669	-6	-13
Ethylene	32,811	29,847	31,383	28,680	24,501	29,418	28,667	29,904	25,955	25,172	22,475	10	4
Ethylene dichloride	14,597	12,101	10,710	11,506	7,619	9,974	11,108	11,794	11,001	10,997	8,342	21	6
Ethylene glycol	4,737	4,178	4,823	4,425	4,309	4,143	4,386	4,729	3,904	3,675	3,335	13	4
Ethylene oxide	5,935	5,430	5,699	5,534	4,987	4,937	5,220	5,665	5,012	4,364	4,184	9	4
2-Ethylhexanol	570	536	541	387	325	389	367	318	420	493	450	6	2
Formaldehyde, 37% ^h	5,861	5,606	5,815	5,465	4,817	5,721	5,555	5,971	6,381	6,046	5,449	5	1
Isopropyl alcohol	1,273	1,235	1,394	1,209	1,380	1,669	1,836	1,900	1,730	1,888	1,936	3	-4
Maleic anhydride	350	394	359	299	260	293	304	323	341	294	264	-11	3
Methanol, synthetic	7,323	5,003	8,186	7,982	7,555	8,577	7,153	7,367	6,443	6,453	6,242	46	2
Methyl chloride	412	410 ^a	482	409	366	405	362	463	454	476	378	0	1
Methyl ethyl ketone	582	537	543	531	468	614	692	716	644	635	631	8	-1
Methyl methacrylate	941	858	917	844	721	592	564	633	570	478	538	10	6
Methylchloroform	648	869	675	586	595	611	587	656	661	512	428	-25	4
Methylene chloride	559	467	607	584	532	891	780	931	na	745	na	20	na
Perchloroethylene	414	678	573	547	585	691	765	773	725	614	669	-39	-5
Phenol, synthetic ⁱ	2,921	2,841	2,889	2,638	2,023	2,578	2,568	2,981	2,682	2,338	2,121	3	3
Phthalic anhydride	864	820	870	838	684	870	818	1,013	978	926	902	5	0
Propylene ^j	17,343	14,887	15,559	13,959	12,535	13,482	13,676	14,198	13,014	13,328	10,030	16	6
Propylene glycol	606	500	462	484	400	473	488	610	547	489	517	22	2
Styrene	7,853	7,622	7,709	6,802	5,942	6,679	6,856	7,484	7,186	6,867	6,301	3	2
Terephthalic acid, dimethyl ester ^k	7,684	6,490	5,912	5,626	4,843	6,235	6,054	6,159	5,954	5,410	5,051	18	4
Toluene, mg ^{b,l}	804	698	728	780	714	852	1,010	1,001	1,046	1,008	990	15	-2
Vinyl acetate	2,205	2,112	2,024	1,963	1,876	1,936	1,922	1,982	1,692	1,586	1,481	4	4
Vinyl chloride	8,415	9,463	6,084	6,875	4,902	6,874	6,466	6,389	6,941	5,986	5,677	-11	4
<i>o</i> -Xylene	789	675	688	781	802	918	995	1,082	1,013	985	854	17	-1
<i>p</i> -Xylene	4,995	4,779	4,264	4,114	3,391	4,532	4,238	4,650	3,516	3,172	2,911	5	6

^a Preliminary. ^b Tar distillers and coke-oven operators not included. ^c Specification grades. ^d Rubber grade. ^e Includes straight-chain dodecylbenzene, tridecylbenzene, and other straight-chain alkylbenzenes. ^f Preliminary figure, final figure not available. ^g Mono-, di-, and triethanolamines. ^h By weight. ⁱ Does not include data for coke ovens and gas-retort ovens. ^j All grades. ^k Includes both acid and dimethyl ester (DMT), without double counting. ^l High-purity toluene, includes material used in blending motor fuel. mg = millions of gallons. na = not available. Source: International Trade Commission

INORGANICS: Production growth weak at best, with sharp declines for farm-related chemicals

Thousands of tons unless otherwise noted	Production											Annual change	
	1986 ^a	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1985-86	1976-86
Aluminum sulfate ^b	1,258	1,268	1,129	1,119	1,154	1,294	1,286	1,315	1,309	1,255	1,202	-1%	0%
Ammonia, c,d 100%	14,005	17,319	16,692	14,072	15,801	19,044	19,653	18,634	17,119	17,765	16,716	-19	-2
Ammonium nitrate, e 100%	5,556	6,776	7,146	6,240	7,091	8,861	9,128	8,293	7,210	7,177	7,186	-18	-3
Ammonium sulfate, d,f 100%	2,085	2,093	2,067	1,956	1,768	2,185	2,136	2,363	2,449	2,264	2,010	0	0
Chlorine gas ^g	10,426	10,402	10,700	9,960	9,176	10,763	11,421	12,291	11,052	10,573	10,378	0	0
Hydrochloric acid, h 100%	2,929	2,807	2,732	2,468	2,450	2,574	2,888	3,090	2,793	2,668	2,542	4	1
Hydrogen, i,j bcf, 100%	123	121	109	103	88	105	107	106	90	85	82	2	4
Nitric acid, k 100%	6,562	7,631	7,726	6,768	7,390	9,093	9,231	8,916	7,934	7,987	7,791	-14	-2
Nitrogen gas, i,j bcf, 100%	671	665	661	560	483	490	479	427	379	328	289	1	9
Oxygen, bcf, i,j 100%	399	393	375	346	349	431	431	456	430	392	388	2	0
Phosphoric acid, 100% P ₂ O ₅	9,206	10,518	11,370	9,767	8,253	9,958	10,848	10,318	9,637	8,745	7,949	-12	1
Phosphorus ^m	362	359	386	366	361	426	432	460	441	430	437	1	-2
Sodium chlorate, 100%	273	259	295	323	291	297	312	269	265	251	199	5	3
Sodium hydroxide, 100%	11,055	10,811	10,914	10,039	9,385	10,621	11,625	12,759	11,309	11,000	10,516	2	1
Sodium phosphate ⁿ	633	625	675	669	651	696	727	757	739	717	724	1	-1
Sodium silicate ^o	787	737	685	710	664	771	805	813	829	760	747	7	1
Sodium sulfate, p 100%	800	1,203	901	914	884	1,111	1,140	1,121	1,174	1,199	1,232	-33	-4
Sulfuric acid, q 100%	36,822	39,651	41,802	36,583	33,233	40,742	44,158	43,204	41,314	38,337	34,878	-7	1
Titanium dioxide, r 100%	917	860	835	760	660	761	727	742	701	687	713	7	3
Urea	6,029	6,678	7,433	6,137	6,470	8,062	7,830	7,000	6,273	5,072	4,498	-10	3

a Preliminary. b Commercial, 17% Al₂O₃; includes municipalities. c Synthetic anhydrous. d Excludes by-product ammonia liquor and ammonium sulfate. e Original solution. f Synthetic and noncoker by-product. g Includes quantities liquefied for use, storage, or shipment. h Includes anhydrous hydrochloric acid production. i High- and low-purity gas. j Liquid and gas; excludes amounts vented and used as fuel, and amounts produced in petroleum refineries for captive use. k Includes unspecified amounts of nitric acid produced but not withdrawn from the system. l Excludes amounts produced and consumed in making synthetic ammonia or ammonia derivatives. m Elemental, white (yellow), and red. n Triphosphate (100% Na₃P₂O₇). o Soluble silicate glass (water glass), solid and liquid (anhydrous); excludes amounts produced and consumed in making meta-, ortho-, and sesquisilicates. p Anhydrous, high and low purity, and Glauber's salt. q Gross (new and fortified). r Composite and pure. Note: bcf = billions of cubic feet. Sources: Department of Commerce, International Trade Commission

Man-made noncellulosic fibers output

Billions of lb



MAN-MADE FIBERS: Nylon, olefins production up in 1986

Millions of lb	Production											Annual change	
	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1985-86	1976-86
NONCELLULOSIC FIBERS													
Acrylic ^a	616	631	671	671	624	691	779	761	726	709	621	-2%	0%
Nylon	2514 ^b	2343 ^b	2412 ^b	2419 ^b	1927	2332	2358	2720	2550	2326	2075	7	2
Olefins ^c	1393	1249	997	906	723	785	748	759	692	635	577	12	9
Polyester	3305	3341	3392	3544	3169	4176	3989	4178	3800	3642	3340	-1	0
CELLULOSIC FIBERS													
Acetate ^d	619	558	199	229	196	261	316	324	308	290	298	11	-3
Rayon	na	na	421	401	388	509	490	606	597	596	543	na	na
GLASS FIBER	na	na	1394	1168	899	1041	867	1014	923	787	676	na	na
TOTAL ^e	8447	8122	9486	9336	7926	9795	9547	10362	9596	8987	8130	4%	nc

Note: Totals may not add because of rounding. a Includes modacrylic. b Excludes aramid in 1983-86. c Includes olefin yarn and monofilaments and olefin and vinyon staple, tow, and fiberfill. d Includes diacetate and triacetate; excludes production for cigarette filters. e Totals for 1985 and 1986 exclude glass fiber. na = not available. nc = not comparable. Source: Textile Economics Bureau

1 Production by the U.S. Chemical Industry

SYNTHETIC RUBBER: Total production recovered a bit in 1986

Thousands of metric tons	Production											Annual change	
	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1985-86	1976-86
Styrene-butadiene rubber ^a	792	735	958	904	878	1032	1074	1378	1395	1395	1333	8%	-5%
Polybutadiene	325	330	359	333	288	342	311	397	378	361	352	-2	-1
Nitrile	58	53	67	55	45	66	63	75	73	70	73	9	-2
Ethylene-propylene	230	215	215	175	123	178	144	175	174	158	130	7	6
Other ^b	582	505	556	468	498	404	423	509	453	432	415	15	3
TOTAL	1967	1838	2155	1935	1830	2022	2015	2534	2473	2416	2303	8%	-1%

^a Excludes high-styrene latex. ^b Includes butyl, polychloroprene, polyisoprene, silicone, and other synthetic elastomers. Some values are estimated. Source: Rubber Manufacturers Association

Plastics production

Billions of lb



PLASTICS:
Output rises
again for fourth
straight year

Millions of lb ^a	Production											Annual change	
	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1985-86	1976-86
THERMOSETTING RESINS													
Epoxy ^b	398	385	406	334	286	336	315	361	299	261	244	3%	5%
Polyester ^c	1,271	1,223	1,232	1,084	865	997	947	1,147	1,209	1,061	1,042	4	2
Urea	1,271	1,210	1,199	1,172	998	1,165	1,165	1,367	1,122	963	821	5	4
Melamine	173	192	210	180	158	179	167	200	202	200	186	-10	-1
Phenolic ^d	2,735 ^e	2,621 ^e	2,502 ^e	2,477 ^e	2,006 ^e	2,333 ^e	1,499	1,781	1,617	1,458	1,340	4	nc
TOTAL	5,846	5,631	5,549	5,247	4,313	5,010	4,093	4,656	4,449	3,943	3,633	4%	nc
THERMOPLASTIC RESINS													
Polyethylene													
Low density ^f	8,903	8,889	8,413	8,041	7,503	7,693	7,291	7,793	7,111	6,471	5,813	0	4
High density ^g	7,182	6,671	6,085	5,689	4,928	4,695	4,405	5,010	4,201	3,652	3,125	8	9
Polypropylene	5,812	5,139	4,940	4,433	3,477	3,955	3,648	3,841	3,074	2,747	2,632	13	8
Styrene-acrylonitrile	92	87	99	93	91	107	111	124	120	115	113	6	-2
Polystyrene	4,470	4,054	3,838	3,570	3,191	3,621	3,521	4,005	3,823	3,446	3,195	10	3
Acrylonitrile-butadiene-styrene and other styrene polymers ^h	2,195	2,036	2,127	1,889	1,380	1,745	1,705	2,107	2,012	1,882	1,744	8	2
Polyamide, nylon type	465	399	396	321	228	312	274	327	275	254	247	17	7
Polyvinyl chloride and copolymers	7,256	6,772	6,760	6,067	5,326	5,707	5,470	6,119	5,723	5,253	4,716	7	4
Thermoplastic polyester	1,175	965	899	778	648	609	na	na	na	na	na	22	na
Other vinyl resins ⁱ	195	190	187	186	177	208	196	220	197	197	225	3	-1
TOTAL	37,745	35,202	33,744	31,067	26,949	28,652	26,621	29,546	26,536	24,017	21,810	7%	6%

Note: Totals are for those products listed and exclude some small-volume plastics. ^a Dry-weight basis unless otherwise specified. ^b Unmodified. ^c Unsaturated. ^d Includes other tar acid resins. ^e Gross-weight basis. ^f Density 0.940 and below. ^g Density above 0.940. ^h Includes styrene-butadiene copolymers and other styrene-based polymers. ⁱ Includes polyvinyl butyral, polyvinyl formal, and polyvinylidene chloride. na = not available. nc = not comparable. Source: Society of the Plastics Industry

Fertilizer production

Millions of tons



FERTILIZERS:
Production, supply
down in all
categories

Note: Total U.S. production of nitrogen, phosphate, and potash fertilizer. Years ending June 30.
Source: Department of Agriculture

Thousands of tons	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	Annual change	
NITROGEN (N)													
Domestic production	10,425	12,532	10,364	9,855	11,598	13,036	12,323	11,106	10,466	10,789	10,572	-17%	0%
Imports	3,979	3,598	3,940	2,654	2,531	2,455	2,566	2,165	1,866	1,842	1,218	11	13
Exports	2,068	3,227	2,080	2,074	2,499	3,088	2,641	2,468	1,778	1,251	1,239	-36	5
Domestic supply	12,336	12,903	12,224	10,435	11,630	12,403	12,248	10,803	10,554	11,380	10,551	-4	2
PHOSPHATE (P ₂ O ₅)													
Domestic production	8,581	10,666	9,611	8,043	7,818	10,471	10,012	9,432	8,245	7,793	7,199	-20	2
Imports	111	141	121	133	193	250	239	236	229	245	221	-21	-7
Exports	3,768	5,547	4,352	3,916	3,751	4,381	3,925	3,848	3,290	2,501	2,175	-32	6
Domestic supply	4,924	5,260	5,380	4,260	4,260	6,340	6,326	5,820	5,184	5,537	5,245	-6	-1
POTASH (K ₂ O)													
Domestic production	1,052	1,413	1,653	1,859	1,831	2,262	2,474	2,519	2,176	2,584	2,313	-26	-8
Imports	4,759	5,355	5,164	4,402	4,797	5,487	5,403	5,085	4,948	4,955	3,910	-11	2
Exports	494	588	528	624	641	876	1,048	999	1,003	994	911	-16	-6
Domestic supply	5,317	6,180	6,289	5,637	5,987	6,873	6,829	6,605	6,121	6,545	5,312	-14	0

Note: Years ending June 30. Source: Department of Agriculture

NITROGEN: Output drops steeply in 1986

	Production											Annual change	
Thousands of tons (N)	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1986-85	1978-86
Ammonia ^a	4,610	5,255	4,179	3587	5,032	5,348	5,270	4,603	4,063	4,307	4,594	-12%	0%
Ammonium nitrate ^{b,c}	704	836	913	943	1,105	1,157	1,096	1,137	1,044	1,169	1,265	-16	-6
Ammonium sulfate ^c	482	484	517	395	432	502	521	509	497	547	562	0	-2
Urea	1,624	1,999	1,786	1692	1,684	1,383	1,572	1,201	1,001	937	941	-19	6
All other	3,005	3,958	2,969	3238	3,345	3,964	3,864	3,656	3,871	3,829	3,210	-24	-1
TOTAL	10,425	12,532	10,364	9855	11,598	12,354	12,323	11,106	10,476	10,789	10,572	-17%	0%

Note: Years ending June 30. ^a Includes aqueous solutions. ^b Includes ammonium nitrate-limestone mixtures. ^c Adjusted for estimated quantity going into nonfertilizer uses. Source: Department of Agriculture.

PHOSPHATE: After two years of increases, production plummets

Thousands of tons (P ₂ O ₅)	Production										Annual change		
	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1985-86	1978-86
Ammonium phosphate ^a	4984	6525	6156	5026	4434	6,243	5,519	5082	4548	4118	3380	-24%	4%
Concentrated superphosphate	1093	1145	1172	1184	1151	1,694	1,737	1901	1768	1750	1682	-5	-4
Normal and enriched superphosphate	70	102	113	110	153	376	384	320	303	376	414	-31	-16
All other	2434	2894	2170	1723	2080	2,613	2,372	2129	1626	1549	1743	-16	3
TOTAL	8581	10666	9611	8043	7818	10,926	10,012	9432	8245	7793	7199	-20%	2%

Note: Years ending June 30. ^a Liquid and solid, excluding that combined with potash salts in the process of manufacture. Source: Department of Agriculture

1 Production by the U.S. Chemical Industry

POTASH: Production in U.S. continues its long downhill slide

Thousands of tons (K ₂ O)	Production											Annual change	
	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1985-86	1978-86
Potassium chloride	762	1107	1248	1456	1383	2007	1874	2082	1770	2098	1893	-31%	-9%
Potassium sulfate	255	271	370	368	413	481	565	402	371	451	385	-6	-4
All other	35	35	35	35	35	35	35	35	35	35	35	0	0
TOTAL	1052	1413	1653	1859	1831	2523	2474	2519	2176	2584	2313	-26%	-8%

Note: Years ending June 30. Source: Department of Agriculture

PESTICIDES: Production increased in 1985 but remained well below pre-1982 levels

Millions of lb	Production										Annual change		
	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	1984-85	1975-85
Herbicides ^a	756	716	604	623	839	806	657	664	674	656	788	6%	0%
Insecticides ^b	370	350	306	379	448	506	617	605	570	566	660	6	-6
Fungicides	109	123	106	111	143	156	155	148	143	142	155	-11	-3
TOTAL	1235	1189	1017	1113	1430	1468	1429	1416	1388	1364	1603	4%	-3%

a Includes plant growth regulators. b Includes rodenticides, soil conditioners, and fumigants. Source: International Trade Commission

Paints and coatings shipments

Millions of gal



COATINGS: Shipments have climbed since 1982

Millions of gal	Shipments								Change
	1986	1985	1984	1983	1982	1981	1980	1979	1985-86
Architectural	481	477	457	433	374	417	439	472	1%
Product ^a	339	317	336	294	280	312	316	351	7
Special purpose	148	145	145	130	129	129	135	116	2
TOTAL	968	939	938	857	783	858	890	939	3%

a For original equipment manufacturers. Source: Department of Commerce

AEROSOLS: Output rose last year, with personal, automotive, and industrial products strong

Millions of units	Production										Annual change		
	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1985-86	1978-86
Personal products	952	879	832	747	628	645	637	772	729	720	981	8%	0%
Household products	635	630	603	586	556	575	580	653	628	600	532	1	2
Automotive and industrial products	375	342	337	303	286	302	310	300	275	230	185	10	7
Paints and finishes	297	290	307	300	295	313	310	302	309	331	306	2	0
Insect sprays	193	190	184	180	166	173	150	199	132	120	114	2	5
Food products	136	140	138	132	131	145	130	141	143	125	151	-3	-1
Animal products	22	15	16	19	19	14	15	18	15	18	16	47	3
Miscellaneous	18	23	15	15	13	28	30	14	a	5	10	-22	6
TOTAL	2628	2509	2433	2283	2096	2195	2163	2398	2232	2150	2295	5%	1%

a Not shown separately. Source: Chemical Specialties Manufacturers Association

CHLOROFLUOROCARBONS: U.S. production continues to rebound after late-70s slump

Millions of lb	Production											Annual change	
	1986*	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1985-86	1978-86
Chlorodifluoromethane (F-22)	274	235	254	236	174	252	227	211	206	179	170	17%	5%
Dichlorodifluoromethane (F-12)	322	302	337	290	258	325	295	294	327	358	393	7	-2
Trichlorofluoromethane (F-11)	201	176	185	215	140	163	158	167	194	213	256	14	-2
All other fluorinated hydrocarbons ^b	na	306	337	279	na	na	na	202	169	171	181	na	na
TOTAL	na	1019	1113	1020	na	na	na	874	916	921	1000	na	na

a Preliminary. b Includes other fluorochlorinated hydrocarbons. na = not available. Source: International Trade Commission

Chemical earnings stage a comeback

Although sales growth in the chemical industry in 1986 was lackluster at best, it was a good year for chemical firms in terms of profitability. Cost-cutting measures and production efficiencies that most chemical firms had instituted over the previous five years finally bore fruit.

The industry, by cutting its staffs, introducing streamlined processes, closing old and inefficient plants, and selling or closing marginally profitable or unprofitable businesses, cut its breakeven point drastically. As a result of this new operating leverage, a small rise in demand, and thus capacity use, can provide a large increase in profitability.

Another reason earnings grew faster than sales in 1986 is that raw materials were lower priced through much of the year. This was a two-edged sword, however, for although it gave companies a cost break, it also served to put pressure on prices as customers expected the lower costs to be passed through to them.

Sales were affected in much of 1986 by a string of problems that had been going on for some time. These include weak export markets and competition from imports for domestic sales. It was only in the latter half of the year that the foreign trade picture began to brighten. But when it did, the U.S. chemical trade surplus for 1986 was 8% higher than it was in 1985, ending a five-year slide. Although the trade surplus is not back to levels of the late 1970s, the improvement may foretoken improving exports during the next couple years.

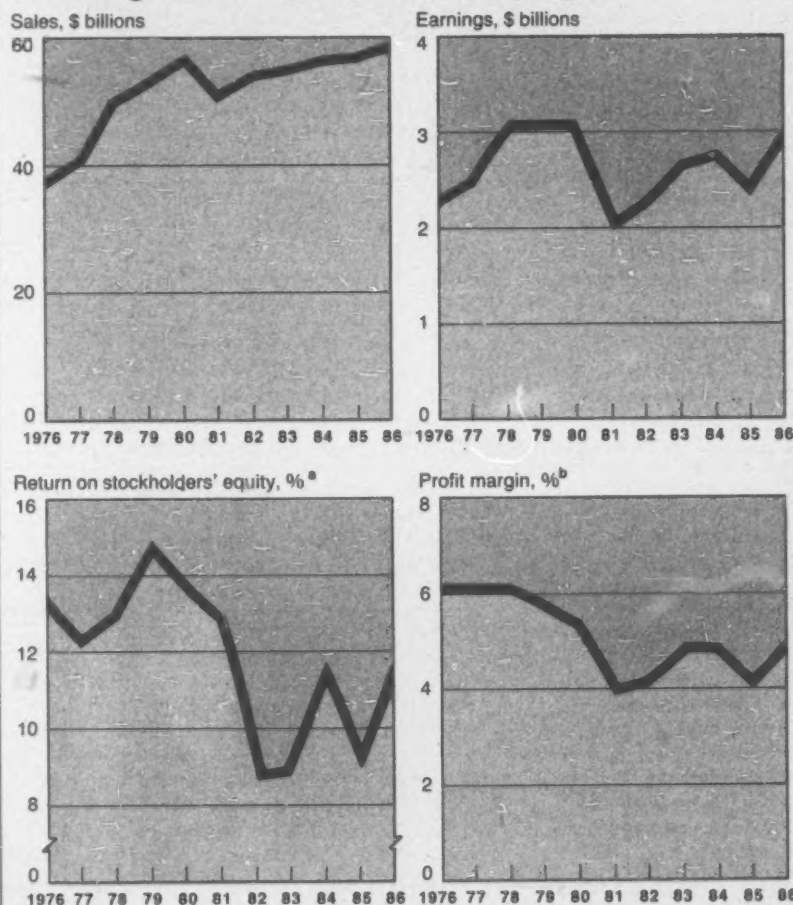
Then, too, pricing was extremely poor, with prices for many chemicals ending the year lower than at the start. Besides pressure put on by customers for passthroughs of lower manufacturing costs, cheaper imports undercut prices for some of the year, and low demand in some U.S. markets also pulled overall prices down.

Some markets were still weak in 1986. Although many large-volume outlets for chemicals, such as plastics, picked up well, in line with rising demand in such end-use markets as autos and housing, others did not. Chief among these was the farm chemicals market; the long suffering agriculture economy put the squeeze on pesticides and, especially, fertilizers.

As a result, chemical industry sales

rose only 3% from the year before, about in line with inflation in the U.S., but at least in contrast to the deflation in the industry itself. The earnings leverage in the industry, however, pushed earnings up 25%. Thus, profitability improved handsomely, with profit margins climbing to 5.0% from 4.0% in 1985 and return on stockholders' equity increasing to 11.7% from 9.0% the year before.

Profitability improved for major chemical producers last year as earnings rebounded on a modest sales gain



Note: Based on data for 30 major chemical companies. ^a After-tax earnings as a percentage of year-end stockholders' equity. ^b After-tax earnings as a percentage of sales.

TOP 100 CHEMICAL PRODUCERS: Rankings are shuffled as the industry changes its structure

Rank ^a 1989 1995		Chemical sales 1995 (\$ millions)	Change from 1985	Chemical sales as % of total sales	Industry classification	Chemical operating profits ^b (\$ millions)	Change from 1985	Chemical operating profits as % of total operating profits	Operating profit margin ^c	Identifiable chemical assets (\$ millions)	Chemical assets as % of total assets	Operating return on chemical assets ^d
1	1 Du Pont	\$11,839	5.2%	43.6%	Diversified	\$1764	102.8%	52.1%	14.9%	\$8739	36.2%	20.2%
2	2 Dow Chemical	8,863	-6.8	79.8	Basic chemicals	978	138.0	76.1	11.0	8139	66.5	12.0
3	3 Exxon	6,079	-8.9	8.1	Petroleum	817	112.2	9.9	13.4	5508	7.9	14.8
4	5 Union Carbide	5,001	26.3	78.8	Basic chemicals	748	81.1	94.6	15.0	5047	74.3	14.8
5	6 Atlantic Richfield	4,915	29.2	32.8	Petroleum	398	445.2	64.7	8.1	2085	9.7	19.1
6	4 Monsanto	4,701 ^e	-9.6	68.3	Basic chemicals	896	87.8	141.1	19.1	3860	46.7	23.2
7	12 BASF Wyandotte	3,600 ^e	38.5	100.0	Basic chemicals	na	na	na	na	na	na	na
8	7 Shell Oil	3,292	-0.8	19.6	Petroleum	648	292.7	35.1	19.7	3447	13.1	18.8
9	9 Amoco	2,928	0.8	14.5	Petroleum	467	55.0	23.0	15.9	2545	11.0	18.3
10	8 Celanese	2,891	-5.1	100.0	Basic chemicals	258	103.1	100.0	8.9	na	na	na
11	17 Allied-Signal	2,819	37.2	23.9	Diversified	346	77.4	32.9	12.3	2161	19.2	16.0
12	10 W. R. Grace	2,492	-13.1	66.9	Specialty chemicals	285	21.8	1187.5	11.4	1633	53.1	17.5
13	15 Mobil	2,391	5.5	4.8	Petroleum	205	153.1	4.5	8.6	2103	5.7	9.7
14	13 Eastman Kodak	2,379	1.3	20.6	Photo equipment	227	24.0	31.4	9.5	2266	17.6	10.0
15	11 Chevron	2,378	-8.9	9.1	Petroleum	147	def	20.6	6.2	3207	9.3	4.6
16	14 General Electric	2,331	-0.7	6.3	Diversified	424	-9.0	9.8	18.2	3602	10.4	11.8
17	22 Occidental Petroleum	2,088 ^f	28.8	13.0	Petroleum	176	75.1	36.2	8.4	2393	13.7	7.3
18	18 Rohm & Haas	2,067	5.1	100.0	Basic chemicals	280	3.7	100.0	13.5	1470	100.0	19.0
19	19 American Cyanamid	1,821	-0.5	47.7	Basic chemicals	135	66.8	38.3	7.4	1275	49.6	10.6
20	21 Air Products ^g	1,798	7.4	90.7	Basic chemicals	363	16.2	129.4	20.2	2173	80.3	16.7
21	23 Mobay	1,710	6.9	100.0	Basic chemicals	150	0.1	100.0	8.8	na	na	na
22	20 Hercules	1,709	-2.0	65.4	Basic chemicals	101	114.9	49.5	5.9	1464	71.6	6.9
23	15 Phillips Petroleum	1,698	-25.1	17.0	Petroleum	299	36.5	30.3	17.6	1053	8.5	28.4
24	25 Borden	1,638	7.0	32.7	Dairy products	176	36.4	35.3	10.7	1399	40.3	12.6
25	24 Ciba-Geigy	1,490	-3.2	61.3	Specialty chemicals	na	na	na	na	na	na	na
26	26 Ashland Oil	1,477	-1.5	20.3	Petroleum	71	4.4	15.0	4.8	527	13.9	13.5
27	27 B. F. Goodrich	1,458	5.4	57.1	Rubber products	134	68.5	79.9	9.2	1199	82.5	11.1
28	29 FMC	1,399	11.0	46.6	Machinery	224	56.8	71.6	16.0	1344	50.0	16.7
29	28 American Hoechst	1,331 ^h	-2.2	77.8	Basic chemicals	na	na	na	na	na	na	na
30	31 Texaco	1,279	4.8	4.0	Petroleum	91	658.3	3.9	7.1	1114	3.2	8.2
31	30 Ethyl	1,272	2.5	57.0	Basic chemicals	247	24.8	69.0	19.4	829	48.4	29.8
32	34 Olin	1,114	-2.9	65.3	Basic chemicals	80	72.7	50.3	7.2	840	59.6	9.5
33	37 National Distillers	1,087	4.7	62.8	Alcoholic beverages	124	72.6	67.0	11.4	1385	47.7	8.9
34	40 Dow Corning	1,085	20.4	100.0	Specialty chemicals	111 ^h	16.2	100.0	10.2	na	na	na
35	36 International Minerals ⁱ	1,077	1.9	87.1	Agrochemicals	35	-74.2	57.1	3.2	2042	84.1	1.7
36	41 National Starch	1,064	20.7	100.0	Specialty chemicals	140	22.4	100.0	13.2	743	100.0	18.9
37	32 Unocal Corp.	1,056	-13.2	12.6	Petroleum	46 ^h	-20.7	26.1	4.4	722	7.1	6.4
38	38 Borg-Warner	1,043	12.3	30.9	Auto equipment	153	25.3	43.8	14.7	562	23.6	27.3
39	44 Lubrizol	889	10.6	91.0	Specialty chemicals	140	49.5	108.6	15.7	589	67.1	23.7
40	42 PPG Industries	843 ^j	0.2	18.0	Glass products	103	28.3	14.8	12.2	1185	25.5	8.7
41	85 Aluminum Co. of America	840 ^e	209.6	18.0	Nonferrous metals	na	na	na	na	na	na	na
42	51 Pennwalt	777	14.2	70.1	Basic chemicals	93	57.3	78.8	12.0	649	73.8	14.3
43	49 Cabot ^g	769	7.9	58.7	Specialty metals	138	55.9	69.3	17.9	494	32.7	27.9
44	39 CF Industries	766	-16.8	100.0	Agrochemicals	-45	def	def	def	842	100.0	def
44	43 Reichhold Chemicals	766	-6.9	100.0	Basic chemicals	53	150.7	100.0	7.0	458	100.0	11.6
46	32 Aristech	751	-4.9	100.0	Basic chemicals	98	131.5	100.0	13.0	na	na	na
47	50 Nalco Chemical	738	7.9	100.0	Specialty chemicals	108	-11.0	100.0	14.7	586	100.0	18.4
48	58 NL Industries	734	30.1	57.2	Petroleum services	na	na	na	na	na	na	na
49	48 Eli Lilly	699	-2.0	18.8	Drugs	53	-39.8	5.8	7.6	766	16.7	6.9
50	54 Engelhard	666	11.3	29.1	Specialty metals	77	24.2	80.5	11.6	507	58.2	12.7

a Revised from C&EN, May 4. b Operating profit is sales less administrative expenses and cost of sales. c Operating profit from chemicals as a percentage of chemical sales. d Chemical operating profit as a percentage of identifiable chemical assets. e Chemical sales include significant amounts of nonchemical products. f Does not include all chemical sales. g Fiscal year ends Sept. 30. h Chemical net profits. i Fiscal year ends June 30. j Fiscal year ends Nov. 30. k Fiscal year ends Oct. 31. na = not available. def = deficit.

and attracts new entrants

Rank* 1986 1985	Chemical sales 1986 (\$ millions)	Change from 1985	Chemical sales as % of total sales	Industry classification	Chemical operating profits* (\$ millions)	Change from 1985	Chemical operating profits as % of total operating profits	Operating profit margin*	Identifiable chemical assets (\$ millions)	Chemical assets as % of total assets	Operating return on chemical assets*
51 53 Morton Thiokol ^l	\$652	5.8%	33.4%	Diversified	\$ 87	-2.6%	33.9%	13.4%	\$580	43.1%	15.1%
52 56 Terra Chemicals	626	9.0	100.0	Agrochemicals	na	na	na	na	na	na	na
53 64 International Flavors	621	23.9	100.0	Specialty chemicals	144	22.8	100.0	23.3	673	100.0	21.5
54 45 Williams Cos.	613	-17.4	33.0	Agrochemicals	na	na	na	na	na	na	na
55 52 Koppers	589	-4.8	42.2	Diversified	40	def	25.9	6.7	342	33.6	11.6
56 — Georgia Gulf	583	-4.9	100.0	Basic chemicals	72	-2.6	100.0	12.4	265	100.0	27.3
57 47 Farmland Industries	574	-20.4	21.1	Agricultural supplies	-38	def	def	def	342	45.8	def
58 — Huntsman Chemical	570	na	100.0	Basic chemicals	na	na	na	na	na	na	na
59 61 Vista Chemicals ^g	550	5.5	100.0	Basic chemicals	91	na	100.0	16.5	na	na	na
59 62 Soltex	550	6.8	100.0	Basic chemicals	na	na	na	na	na	na	na
61 56 Witco	544 ^l	-5.2	40.1	Specialty chemicals	45	-21.3	34.0	8.2	275	33.6	16.2
62 63 Polysar	536	4.4	100.0	Basic chemicals	na	na	na	na	na	na	na
63 67 H. B. Fuller ^l	528	15.5	100.0	Specialty chemicals	39	28.5	100.0	7.5	291	100.0	13.6
64 66 Liquid Air	491	6.9	86.0	Basic chemicals	59	2.2	97.5	12.0	595	83.0	9.9
65 59 Standard Oil	475	-13.9	4.7	Petroleum	11	-59.3	1.5	2.3	347	2.2	3.2
66 65 Kerr-McGee	456	-5.7	18.0	Petroleum	14	-69.6	54.4	3.1	na	na	na
67 — CBI Industries	451	2.6	39.0	Construction	60	-4.5	95.9	13.3	552	47.3	10.9
68 71 American Petrofina	441	9.0	22.5	Petroleum	53	358.4	def	12.0	250	14.5	21.3
69 — Henley Group	435	14.5	13.7	Basic chemicals	60	def	def	13.8	359	7.6	16.7
70 74 Pfizer	416	6.0	9.3	Drugs	41	137.4	4.0	9.8	439	8.5	9.2
71 75 Tyler	388	3.4	40.4	Diversified chemicals	27	-8.9	51.1	7.0	187	37.2	14.5
72 73 Rhône-Poulenc	380	-5.0	100.0	Specialty chemicals	na	na	na	na	na	na	na
73 76 GAF	378	3.6	50.1	Specialty chemicals	108	16.4	77.5	28.6	252	18.7	42.8
74 68 Freeport-McMoRan	374	-17.1	59.4	Agrochemicals	76	-28.2	def	20.2	244	10.3	31.0
75 69 Merck	359	-20.3	8.7	Drugs	50	-14.4	4.8	13.9	431	11.7	11.6
76 79 Betz Laboratories	344	7.8	100.0	Specialty chemicals	63	4.6	100.0	18.4	270	100.0	23.5
77 72 Sun Co.	317	-21.1	3.0	Petroleum	na	na	na	na	na	na	na
78 77 Chemed	314	-6.6	87.4	Specialty chemicals	33	-23.8	82.7	10.5	162	82.6	20.3
79 84 Union Carbide	305	10.9	14.9	Diversified	6	-30.3	2.6	2.0	227	8.3	2.7
80 83 Great Lakes Chemical	300	8.5	100.0	Specialty chemicals	43	-5.9	100.0	14.2	na	na	na
81 86 Ferro	286 ^g	6.8	39.4	Specialty materials	22	62.0	37.4	7.8	162	41.4	13.7
82 90 Loctite	267	15.3	100.0	Specialty chemicals	37	5.5	100.0	13.8	244	100.0	15.1
83 — Henkel	265	-8.0	100.0	Specialty chemicals	na	na	na	na	na	na	na
84 89 Stepan	260	10.1	100.0	Specialty chemicals	14	51.7	100.0	5.4	153	100.0	9.2
85 88 Kaiser Aluminum	254	-0.1	11.5	Nonferrous metals	34	333.3	60.0	13.3	284	8.8	11.9
85 81 Petroilite ^k	254	-12.5	90.7	Specialty chemicals	23	-36.8	94.6	9.0	158	68.8	14.4
85 80 Vulcan Materials	254	-13.2	26.5	Nonmetallic minerals	19	-19.9	12.1	7.7	na	na	na
88 91 Lonza	252	27.9	100.0	Specialty chemicals	na	na	na	na	na	na	na
89 82 Dexter Corp.	245	-12.9	37.6	Rubber products	23	-17.4	30.3	9.5	162	62.6	14.4
90 78 Mississippi Chemical ^l	228	-30.0	100.0	Farm cooperative	-13	def	def	def	265	100.0	def
91 95 Sigma-Aldrich	199	20.9	78.8	Specialty chemicals	53	11.5	84.4	26.4	207	84.4	25.5
92 93 Essex Chemical	184	6.8	89.4	Basic chemicals	32	0.0	115.3	17.4	105	76.3	30.5
93 99 Crompton & Knowles	165	46.1	77.2	Specialty chemicals	15	19.4	65.1	9.0	94	83.5	15.8
94 92 Georgia-Pacific	155	-10.4	2.1	Wood products	na	na	na	na	na	na	na
95 97 First Mississippi	153	1.2	56.8	Agrochemicals	20	-36.3	def	13.0	67	26.1	29.6
96 96 Agway	143	-11.8	4.1	Farm cooperative	na	na	na	na	na	na	na
97 — Quaker Chemical	128	4.4	100.0	Specialty chemicals	14	11.3	100.0	10.8	99	100.0	14.0
98 98 UGI Corp.	113	-3.9	25.4	Natural gas	0	def	def	def	168	28.8	def
99 — LeaRonai	105	-19.5	100.0	Specialty chemicals	10	-26.1	100.0	9.8	65	100.0	15.8
100 100 Lawter Chemicals	104	7.0	100.0	Diversified	20	49.0	100.0	19.0	93	100.0	21.1

2 Finances of the U.S. Chemical Industry

FINANCIAL ANALYSIS: Most measures strengthened in 1986

		Profit margin ^a	Return on invest- ment ^b	Debt as % debt plus equity	% total sales abroad ^c	% total assets abroad ^d	Sales per em- ployee ^e	Dividends as % of net income	CAPITAL SPENDING ^f		R&D as % of sales	Sales as % of assets	Net plant as % of gross plant
									as % of sales	as % of net plant			
SALES OVER \$900 MILLION													
Air Products ^g	1986	6.9%	3.3%	38.9%	19.5%	25.0%	\$119.4	32.9%	18.5%	20.0%	3.1%	73.3%	53.2%
	1985	7.8	3.8	30.9	17.3	18.8	97.8	26.6	21.4	22.0	2.8	70.5	56.1
American Cyanamid	1986	5.3	4.4	25.4	33.6	24.2	110.7	43.6	6.9	20.7	7.3	104.1	47.4
	1985	3.4	2.7	25.8	29.6	21.9	97.1	76.0	5.7	18.0	7.1	103.9	44.3
Cabot ^h	1986	5.6	4.1	41.9	38.4	16.9	198.5	35.4	5.5	11.3	2.6	86.8	53.0
	1985	5.1	4.1	37.9	28.8	15.7	182.8	41.4	10.1	22.7	2.3	88.3	56.3
Dow Chemical	1986	6.7	4.3	39.7	53.5	49.4	216.6	49.1	8.0	16.6	5.4	90.8	42.1
	1985	0.5	0.4	40.0	54.8	46.6	216.9	587.9	7.0	15.7	4.7	97.5	43.2
Ethyl	1986	11.3	10.7	30.2	19.6	8.7	150.4	24.0	8.5	22.5	3.0	92.1	49.3
	1985	7.6	7.5	33.6	28.3	9.2	147.3	31.7	5.8	16.1	3.0	99.4	50.6
B. F. Goodrich	1986	0.5	0.6	34.4	19.1	14.3	214.6	289.9	5.6	16.9	2.2	140.3	58.3
	1985	0.3	0.3	41.7	15.4	15.1	122.2	374.5	6.3	19.4	2.0	141.6	55.1
W. R. Grace	1986	1.2	0.9	45.6	32.3	16.9	90.0	263.0	5.3	12.6	2.5	90.9	48.3
	1985	2.5	1.9	38.8	25.4	16.4	58.3	111.7	6.7	13.4	1.8	95.8	57.1
Hercules	1986	8.7	6.8	24.3	21.1	15.4	104.1	41.4	9.8	22.3	2.7	89.7	51.4
	1985	5.1	4.4	26.5	25.0	14.9	101.7	64.9	9.1	23.4	2.9	97.3	50.1
International Minerals ^h	1986	def	def	48.1	13.2	9.7	84.7	def	8.0	7.5	2.8	48.5	57.7
	1985	7.3	4.4	23.9	17.3	8.3	187.0	59.5	7.1	10.3	na	83.1	52.3
Lubrizol	1986	8.0	7.1	8.4	51.6	31.8	203.4	59.3	4.1	14.0	5.2	111.3	45.0
	1985	6.7	5.7	12.4	47.7	29.5	173.7	78.1	4.4	13.6	4.8	105.7	48.3
Monsanto	1986	6.3	4.7	30.1	32.6	21.2	133.1	46.0	7.6	17.9	8.7	83.2	46.0
	1985	2.7	1.8	38.0	28.5	18.8	120.3	102.7	9.6	21.3	8.1	76.0	44.4
National Distillers	1986	3.2	1.8	37.6	na	na	na	136.1	5.9	7.3	na	59.6	71.9
	1985	3.4	3.3	23.2	na	na	na	96.9	3.3	8.5	na	113.3	60.0
Olin	1986	4.4	3.0	29.7	6.1	8.6	129.3	45.6	7.5	17.8	3.3	110.5	37.6
	1985	2.3	1.6	34.0	7.2	10.3	117.5	86.9	8.8	21.5	3.0	109.6	39.3
Pennwalt	1986	4.7	3.9	33.6	23.5	21.1	115.4	66.0	4.9	12.5	4.1	111.1	50.7
	1985	1.1	0.9	30.1	19.8	18.3	102.4	319.6	8.9	20.7	3.9	105.7	53.3
PPG Industries	1986	6.8	5.1	32.8	25.5	27.4	128.4	35.3	7.6	13.4	4.3	101.0	58.2
	1985	7.0	5.5	35.4	21.5	23.7	115.9	36.4	10.4	18.2	4.0	106.4	59.3
Rohm & Haas	1986	6.7	5.4	21.7	38.7	26.4	171.4	39.1	8.7	27.6	6.4	112.2	39.8
	1985	6.9	5.8	20.7	32.5	26.6	173.2	34.8	7.8	27.4	6.0	118.3	36.7
Union Carbide	1986	2.1	1.2	75.3	28.6	33.2	124.2	110.8	8.4	12.0	2.4	82.5	51.2
	1985	2.3	1.4	30.3	29.2	28.9	98.4	113.4	7.2	11.2	3.1	85.1	54.2
Witco	1986	4.8	5.5	17.0	16.7	15.8	169.4	35.9	4.4	16.3	1.6	165.3	47.8
	1985	3.9	4.3	24.7	14.0	13.5	na	38.4	4.9	19.7	na	178.8	39.3
MEDIAN 1986		5.5%	4.2%	33.2%	25.5%	21.1%	\$129.3	44.6%	7.8%	18.5%	3.1%	91.5%	50.0%
MEDIAN 1985		3.7%	3.6%	30.6%	25.2%	18.6%	\$118.9	77.1%	7.2%	18.8%	3.1%	101.7%	52.8%

Note: Net income is from continuing operations, excluding extraordinary and nonrecurring items where possible. a Net income as a percentage of sales. b Net income as a percentage of current assets plus gross plant. c Consolidated sales only. d Foreign identifiable assets as a percentage of total assets. e Thousands of dollars. f Actual spending on construction of new facilities and purchase of new equipment and land in consolidated businesses. g Fiscal year ended Sept. 30. h Fiscal year ended June 30. i Fiscal year ended Nov. 30. j Fiscal year ended Oct. 31. na = not available. def = deficit.

			Profit margin ^a	Return on invest- ment ^b	Debt as % debt plus equity	% total sales abroad ^c	% total assets abroad ^d	Sales per em- ployee ^e	Dividends as % of net income	CAPITAL SPENDING ^f		R&D as % of sales	Sales as % of assets	Net plant as % of gross plant
										as % of sales	as % of net plant			
SALES LESS THAN \$900 MILLION														
Betz Laboratories	1986	10.3%	11.1%	0.0%	15.4%	16.9%	\$130.2	61.7%	6.6%	17.4%	3.8%	127.7	61.2%	
	1985	11.5	13.3	0.0	13.6	15.1	125.7	55.2	8.5	22.0	3.8	125.9	64.8	
Chemed	1986	2.1	3.4	28.3	12.9	8.7	66.6	205.9	3.0	20.2	0.9	116.3	58.6	
	1985	6.6	12.6	38.8	11.4	10.7	62.1	61.2	2.4	18.8	1.1	144.8	60.0	
Crompton & Knowles	1986	4.2	5.8	22.2	14.4	24.6	162.7	50.6	1.6	12.3	2.1	158.2	49.4	
	1985	3.3	5.1	20.6	17.2	21.9	na	57.9	1.5	11.2	2.0	178.0	50.1	
Essex Chemical	1986	4.3	4.9	38.3	na	na	na	39.8	5.6	16.9	3.2	127.2	58.4	
	1985	4.5	5.1	45.0	na	na	204.3	37.6	4.6	13.7	2.2	134.4	60.5	
First Mississippi ^h	1986	2.6	1.4	36.7	13.6	na	407.4	66.2	11.8	20.3	1.9	88.4	36.0	
	1985	6.7	3.7	32.5	12.6	na	373.7	26.9	23.2	27.0	na	69.1	57.3	
Freeport-McMoRan	1986	4.1	0.9	42.0	na	na	na	156.0	19.5	6.6	na	26.7	69.4	
	1985	15.4	4.1	41.6	na	na	160.5	22.6	28.7	12.8	na	35.1	66.9	
H. B. Fuller ⁱ	1986	3.6	5.7	21.5	42.5	53.1	117.4	17.5	2.5	12.2	2.0	181.5	62.0	
	1985	2.9	4.6	28.0	38.1	51.1	104.1	21.8	3.1	14.8	2.1	180.6	63.9	
GAF Corp.	1986	10.7	8.2	44.4	15.3	6.8	na	4.3	4.5	16.3	1.5	56.0	63.2	
	1985	7.4	7.4	45.5	12.2	6.0	170.2	7.6	6.4	24.3	1.4	83.3	63.0	
Great Lakes	1986	8.9	5.1	43.0	21.6	na	na	1.1	6.1	8.7	3.5	61.1	63.1	
	1985	10.4	7.6	15.9	19.5	na	na	24.0	7.7	15.5	3.4	85.7	57.2	
International Flavors	1986	13.8	10.6	0.0	67.9	49.0	163.3	51.6	4.3	14.3	6.3	92.3	55.8	
	1985	13.9	10.4	0.0	62.2	46.2	135.4	59.8	4.4	13.9	6.8	89.5	56.2	
Lawter International	1986	12.5	12.0	7.8	41.7	38.2	279.7	76.0	1.5	7.1	2.2	110.8	49.1	
	1985	def	def	9.2	34.1	33.7	na	def	3.3	14.1	2.2	115.2	53.4	
Liquid Air	1986	6.1	3.8	41.9	35.7	38.7	130.0	70.0	22.9	27.5	1.8	79.5	59.9	
	1985	5.8	3.7	35.1	34.9	33.6	123.4	67.5	19.1	24.8	1.8	85.7	58.8	
Loctite ^h	1986	8.7	8.6	8.1	47.3	58.3	100.2	31.0	3.5	16.1	3.8	109.3	58.6	
	1985	8.8	8.7	10.4	42.6	48.4	93.7	34.8	4.9	22.7	3.8	105.7	60.3	
Nalco Chemical	1986	8.7	8.4	6.7	23.9	22.3	151.2	73.9	8.6	22.7	4.5	125.5	51.2	
	1985	10.7	10.7	5.8	21.7	21.3	134.7	64.1	8.8	24.2	4.7	126.0	49.7	
Petrolite ⁱ	1986	6.3	5.3	2.9	22.8	25.1	na	74.3	9.0	28.3	4.3	121.7	44.2	
	1985	7.2	7.0	3.6	22.0	20.0	na	58.5	7.6	28.4	4.1	135.5	45.9	
Reichhold Chemicals	1986	2.1	3.2	32.1	20.0	35.5	193.3	37.1	5.3	20.1	3.0	167.0	65.8	
	1985	def	def	36.9	24.3	32.6	180.2	def	11.9	48.0	2.7	165.8	66.4	
Sigma-Aldrich	1986	13.4	12.4	9.5	14.9	14.7	93.7	17.9	14.0	41.2	na	103.3	71.9	
	1985	13.5	13.8	10.2	12.2	12.7	85.9	18.7	8.1	30.1	na	115.1	67.6	
Stepan	1986	2.9	3.2	38.8	na	na	274.1	28.0	5.5	16.7	3.6	170.0	49.1	
	1985	2.3	2.6	62.5	na	na	263.9	36.4	8.1	23.2	3.5	169.3	51.6	
MEDIAN 1986		8.7%	5.7%	20.6%	21.9%	25.7%	\$134.7	38.4%	7.6%	22.0%	3.1%	115.2%	58.8%	
MEDIAN 1985		8.1%	7.7%	18.8%	18.9%	20.4%	\$153.3	45.3%	3.9%	15.6%	2.7%	129.3%	59.9%	

2 Finances of the U.S. Chemical Industry

Capital spending by U.S. chemical producers fell in 1986 as companies still had not put to work all their excess capacity to make product. For 26 chemical makers surveyed by C&EN, capital expenditures dropped 6% from the previous year. However, this decline was fueled not so much by an industrywide cutback in spending but rather by a few companies that sold off parts of their business and thus had less need to invest in new plants and equipment.

Chief among these are Union Carbide, W. R. Grace, and B. F. Goodrich. Carbide sold off a number of businesses, including agricultural chemicals. W. R. Grace sold its retailing operations and carried its fertilizer business as a discontinued operation in anticipation of selling it. And B. F. Goodrich spun off its tire operations into a joint venture with Uniroyal, which cut its capital needs in that area. Excluding these three companies, capital spending among major chemical firms last

year would have been flat to slightly up from the year before.

For 1987, present signs suggest, capital spending in the chemical industry will remain little changed. C&EN's own capital spending survey indicates that expenditures on new plant and equipment in 1987 will be up only 1% over 1986. And the Commerce Department's latest survey shows that capital spending for the broader chemicals and allied products industry will increase just 0.5% in 1987.

INDUSTRY CAPITAL SPENDING: Chemical industry budgets only slight rise for 1987

\$ Billions	1987 ^a	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977
Chemicals	\$ 16.84	\$ 16.75	\$ 16.44	\$ 15.32	\$ 12.96	\$ 12.66	\$ 13.11	\$ 11.63	\$ 9.81	\$ 7.76	\$ 7.35
Iron and steel	4.66	3.35	4.12	3.54	3.25	3.78	3.48	3.44	3.21	2.60	2.88
Nonferrous metals	2.21	1.92	1.88	2.13	1.74	1.90	2.51	2.13	1.65	1.46	1.30
Paper	8.51	8.76	8.59	7.21	5.92	5.60	6.11	6.52	5.24	3.80	3.48
Petroleum	16.21	18.13	26.71	25.53	23.14	26.39	25.98	19.57	15.24	13.16	11.82
Rubber	3.62	3.92	3.66	3.11	2.46	2.16	2.15	2.03	2.46	2.33	1.77
Stone, clay, glass	3.35	3.13	3.40	3.09	2.77	2.90	3.41	3.98	3.99	3.15	2.30
All manufacturing	144.88	142.73	153.48	138.82	116.20	120.68	126.54	112.33	95.92	75.58	67.48

^a Estimate. Source: Commerce Department

Backlog of unspent capital appropriations shrank in 1986

\$ Billions	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976
Chemicals	\$ 6.3	\$ 8.0	\$ 7.8	\$ 7.5	\$ 7.4	\$ 9.4	\$ 9.8	\$ 8.5	\$ 7.2	\$ 7.4	\$ 77.1
Iron and steel	0.4	1.1	2.1	2.2	2.7	5.4	3.9	4.5	4.0	3.6	4.7
Nonferrous metals	1.6	2.3	2.5	3.2	3.2	3.7	3.7	2.9	2.7	2.9	2.4
Paper	4.3	4.3	5.9	4.0	5.1	5.1	4.0	4.2	3.2	2.6	2.0
Petroleum	16.2	26.2	24.7	22.3	22.9	29.7	26.7	16.1	14.6	15.0	12.2
Rubber	2.0	3.1	1.6	1.1	1.0	0.9	1.0	0.9	0.9	0.8	0.7
Stone, clay, glass	1.8	2.0	2.2	1.5	1.6	1.9	2.0	2.3	2.4	2.0	1.5
All manufacturing	69.8	95.0	94.4	73.7	70.8	92.7	91.9	76.7	63.4	56.5	47.5

Note: Figures are for fourth quarter of each year. Source: Conference Board

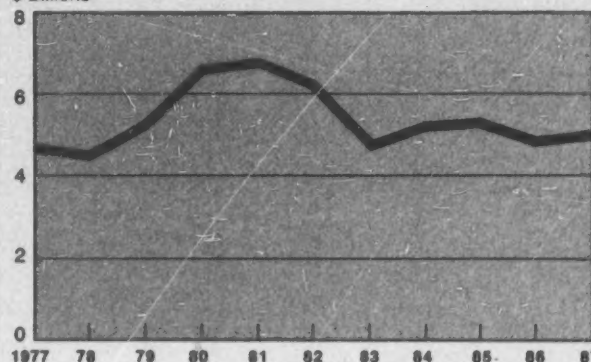
Chemical industry's capital spending abroad continues to grow

\$ Billions ^a	1987 ^b	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977
Chemicals & allied products	\$ 3.6	\$ 3.2	\$ 2.7	\$ 2.4	\$ 2.3	\$ 2.8	\$ 3.0	\$ 3.0	\$ 2.6	\$ 1.9	\$ 2.0
Metals, primary & fabricated	0.8	0.9	0.9	1.0	0.9	1.0	0.8	0.9	0.6	0.6	0.5
Petroleum	10.6	11.1	13.7	14.1	15.9	20.8	15.8	14.8	11.0	9.5	8.9
All manufacturing	18	16.9	14.9	13.6	13.6	16.6	19.2	19.5	15.4	12.0	10.5

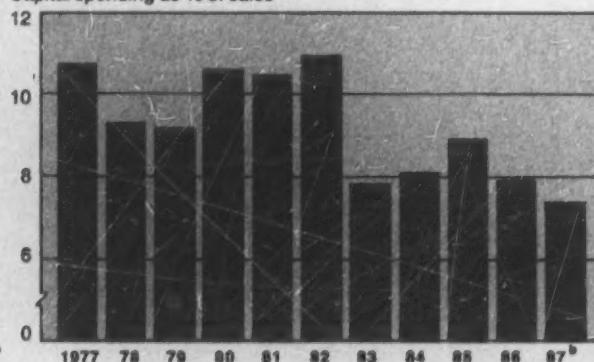
^a By majority-owned foreign affiliates of U.S. companies. ^b Planned. Source: Commerce Department

Chemical capital spending is little changed and is falling as a percentage of sales

\$ Billions^a



Capital spending as % of sales^a



^a Worldwide data for 12 major chemical producers. ^b Estimated. Sources: Company data, C&EN estimates

CHEMICAL CAPITAL SPENDING: Some companies made big cuts in 1986

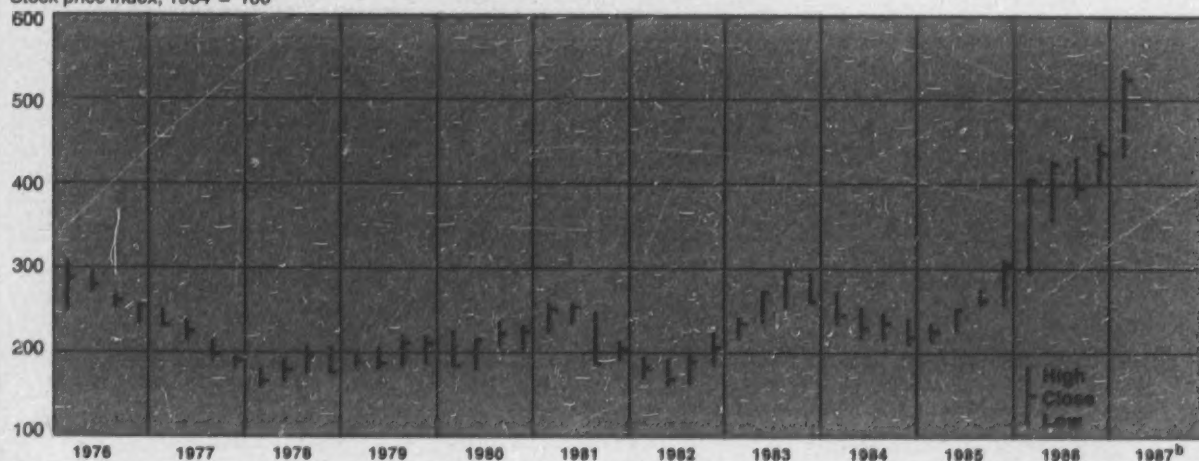
\$ Millions	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976
Air Products	\$ 367	\$ 392	\$ 263	\$ 246	\$ 347	\$ 323	\$ 364	\$ 246	\$ 200	\$ 143	\$ 162
American Cyanamid	263	203	200	165	171	181	196	235	251	235	232
Chemed	9	7	9	5	4	4	4	6	3	3	3
Crompton & Knowles	4	3	3	2	3	7	10	8	5	2	2
Dow Chemical	890	806	781	630	829	1176	1184	1268	1075	1163	1200
Du Pont ^a	1587	1515	1319	1276	1300	1420	1297	864	714	704	876
Essex Chemical	12	9	7	11	25	10	6	4	4	2	5
Ethyl	134	90	103	85	92	141	156	123	96	88	88
B. F. Goodrich	144	202	153	115	144	205	184	192	115	106	86
W. R. Grace	199	348	380	353	560	657	658	514	313	279	234
Great Lakes Chemical	18	21	29	20	29	47	21	18	9	12	6
Hercules	257	234	218	168	174	167	229	186	116	127	150
Loctite	9	11	6	10	11	13	14	9	6	4	2
Lubrizol	41	40	30	25	52	75	92	51	44	23	19
Monsanto	520	645	614	560	673	668	781	566	480	607	647
Nalco Chemical	64	60	53	41	56	59	35	39	34	33	13
National Distillers	102	76	116	71	66	44	49	58	106	88	43
Olin	128	154	165	123	129	186	172	161	163	208	166
Pennwalt	54	90	87	70	76	53	53	66	61	45	40
Petrolite	25	24	11	9	24	15	17	12	7	21	19
PPG Industries	356	452	315	450	452	376	401	252	261	212	177
Reichhold Chemicals	41	35	24	19	21	16	23	26	24	26	22
Rohm & Haas	179	159	124	72	126	182	93	68	66	79	110
Stepan	14	19	12	10	16	12	9	14	14	16	8
Union Carbide	524	649	670	761	1179	1186	1129	831	668	805	965
Witco	60	76	85	55	54	83	73	49	51	29	27
TOTAL	\$6001	\$6320	\$5777	\$5352	\$6611	\$7307	\$7250	\$5864	\$4904	\$5081	\$5302
ANNUAL CHANGE	-5%	9%	8%	-19%	-10%	1%	24%	20%	-3%	-5%	8%

Note: Figures are for worldwide spending on construction, equipment, and land in consolidated businesses. Where possible, acquisition costs and investments in nonconsolidated businesses are excluded. ^a Excludes Conoco. Source: Company data

2 Finances of the U.S. Chemical Industry

Prices of chemical stocks surge higher in recent bull market

Stock price index, 1954 = 100^a



^a C&EN weighted stock price index of American Cyanamid, Dow Chemical, W. R. Grace, Hercules, Monsanto, Rohm & Haas, and Union Carbide; weighted according to number of shares outstanding for each company. ^b First quarter.

SHIPMENTS: Like industry as a whole, chemicals showed no growth in 1986

\$ Billions	1986 ^a	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	Annual change	
All manufacturing industries	\$2347.6	\$2341.2	\$2274.9	\$2047.4	\$1910.1	\$1994.6	\$1851.0	\$1727.2	\$1523.4	\$1358.4	\$1185.6	0%	7%
Chemicals and allied products	214.0	214.3	211.8	190.2	172.8	175.1	161.6	147.7	129.8	118.2	104.1	0	7
Industrial chemicals ^b	70.4	71.6	68.7	59.1	55.8	60.7	56.4	52.3	44.8	41.5	35.6	-2	7
Drugs, soap, and toiletries	61.8	56.1	53.9	50.4	48.6	44.1	41.9	36.7	34.7	30.6	27.6	10	8
Petroleum and coal products	143.0	194.0	200.6	191.6	206.4	220.3	198.7	148.4	103.9	97.5	82.3	-26	6
Rubber and plastic products, nec	47.7	48.2	52.1	50.3	50.2	46.5	47.3	46.8	43.2	39.6	31.8	-1	4
Paper and allied products	109.4	97.6	95.9	85.1	79.0	79.5	72.6	65.2	57.0	52.1	48.2	12	9

^a Preliminary. ^b excluding pigments. nec = not elsewhere classified. Source: Department of Commerce

PRICES: Drugs and paint buck an overall decline for chemical products

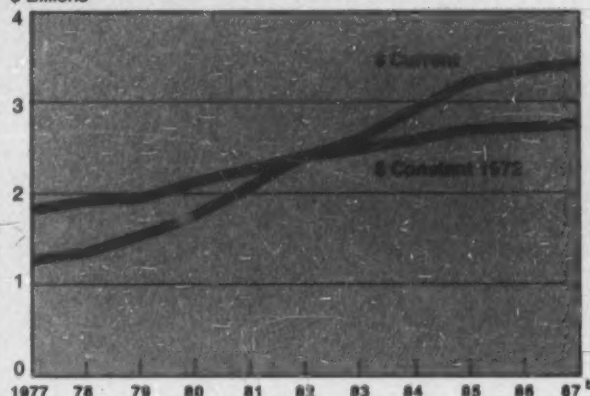
Producer price indexes, ^a 1967 = 100	Annual average											Annual change	
	1986 ^b	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1985-86	1976-86
All commodities	299.8	308.7	310.3	303.1	299.3	293.4	268.8	235.6	209.3	194.2	183.0	-3%	5%
Industrial commodities	312.1	323.8	322.6	315.8	312.3	304.1	274.8	236.5	209.4	195.1	182.4	-4	6
Chemicals and allied products	299.7	303.2	300.8	292.9	292.4	287.6	260.3	222.3	198.8	192.8	187.2	-1	5
Industrial chemicals	322.5	338.3	341.3	342.9	353.0	363.3	324.0	264.0	225.6	223.9	219.3	-5	4
Prepared paint	281.2	276.8	272.5	264.7	262.9	249.6	235.3	204.4	192.3	182.4	174.4	2	5
Paint materials	318.0	333.7	329.7	305.6	304.6	300.1	273.9	241.2	212.7	205.9	189.8	-5	5
Drugs and pharmaceuticals	272.8	256.3	240.0	226.2	210.1	193.5	174.5	159.4	148.1	140.5	134.0	6	7
Fats and oils, inedible	215.1	295.3	371.4	283.7	267.1	295.6	298.0	376.7	315.8	279.0	249.9	-27	-1
Agricultural chemicals and chemical products	275.5	281.3	284.8	280.7	292.7	285.0	257.1	214.4	198.4	187.8	188.4	-2	4
Plastic resins and materials	295.9	304.7	308.6	290.2	283.3	289.2	279.2	235.9	199.8	195.7	194.0	-3	4
Other chemicals and allied products	285.9	284.2	277.5	273.7	269.8	254.2	224.5	191.8	181.6	175.7	170.7	1	5
Rubber and plastics products	246.0	245.9	246.8	243.4	241.6	232.6	217.4	194.3	174.8	167.6	159.2	0	4

^a Formerly called "wholesale price indexes." ^b Preliminary. Source: Department of Labor

2 Finances of the U.S. Chemical Industry

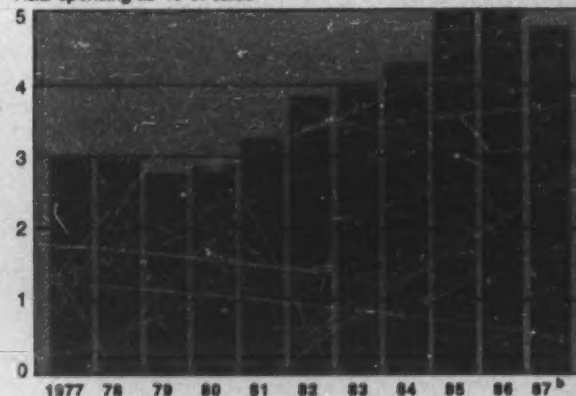
Chemical producers' R&D spending is increasing moderately ...

\$ Billions^a



... but will fall relative to their sales, for the first time in the 1980s

R&D spending as % of sales^b



^a R&D spending by 12 major chemical producers. ^b Estimated. Sources: Company data, Battelle Columbus Laboratories, C&EN estimates

R&D SPENDING: Relatively modest increases last year for chemical producers

\$ Millions	1988	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976
CHEMICAL COMPANIES											
Air Products	\$ 61	\$ 51	\$ 44	\$ 40	\$ 37	\$ 32	\$ 30	\$ 24	\$ 23	\$ 24	\$ 19
American Cyanamid	278	251	232	208	185	166	148	130	108	96	83
Dow Chemical	605	547	507	492	460	404	314	269	232	203	188
Ethyl	47	47	40	39	39	37	34	29	25	28	25
W. R. Grace	94	92	81	73	64	57	45	42	37	32	28
Hercules	71	76	72	74	74	65	57	50	43	40	37
International Flavors	39	34	32	32	31	30	29	27	24	20	16
Lubrizol	51	44	33	37	36	33	28	23	21	19	17
Monsanto	596	470	370	290	264	233	208	161	136	132	114
Naico Chemical	33	32	32	30	33	30	28	21	17	14	12
Olin	56	53	52	49	45	38	31	26	25	25	23
Pennwalt	45	39	36	33	31	27	24	22	23	21	19
Petrolite	12	12	12	13	10	8	7	6	5	5	4
PPG Industries	204	176	150	127	127	119	103	83	70	61	56
Rohm & Haas	133	124	109	100	92	77	67	54	49	45	43
Union Carbide	148	275	265	245	240	207	166	161	156	156	143
TOTAL	\$2474	\$2323	\$2066	\$1881	\$1768	\$1563	\$1318	\$1128	\$993	\$ 920	\$827
ANNUAL CHANGE	6%	12%	10%	8%	13%	19%	17%	14%	8%	11%	9%
PHARMACEUTICAL & DIVERSIFIED COMPANIES											
Allied-Signal	734	470	389	383	177	152	105	70	58	51	42
Du Pont	1156	1144	1097	966	879	718	591	509	461	367	353
Eastman Kodak	1050	976	838	746	710	615	520	459	389	351	335
Eli Lilly	427	370	341	294	267	235	201	178	150	127	114
FMC	146	149	121	102	105	94	81	69	54	44	41
Merck	480	426	393	356	320	274	234	188	161	145	134
Morton Thiokol	38	34	28	21	7	6	6	5	4	4	4
Pfizer	336	287	255	230	199	179	162	139	117	101	91
Upjohn	314	284	247	218	185	162	139	122	109	96	87
TOTAL	\$4689	\$4140	\$3709	\$3315	\$2850	\$2434	\$2038	\$1740	\$1501	\$1286	\$1200
ANNUAL CHANGE	13%	12%	12%	16%	17%	19%	17%	16%	17%	7%	6%

Source: Company data

2 Finances of the U.S. Chemical Industry

INDUSTRY BALANCE SHEET: Increase in current assets is balanced by rise in debt Industrial chemicals and synthetics

Assets	1986	1985	Change	Liabilities and stockholders' equity	1986	1985	Change
	(\$ billions)				(\$ billions)		
Current assets				Current liabilities			
Cash and U.S. bank deposits	\$ 2.52	\$ 1.32	92%	Short-term debt	\$ 3.27	\$ 3.27	0%
Short-term securities	0.95	1.14	-16	Accounts payable	5.76	5.90	-2
Receivables	11.89	12.33	-5	Accrued income taxes	1.31	1.05	3
Inventories	11.21	10.76	4	Current portion of long-term debt	0.85	1.03	-18
Other current assets	3.16	2.50	26	Other current liabilities	8.87	9.40	-6
Total	29.54	28.05	5	Total	20.08	20.64	-3
Fixed assets				Long-term debt	20.87	19.21	9
Depreciable fixed assets	77.42	76.21	2	Other noncurrent liabilities, including deferred taxes and minority interest	8.53	8.19	4
Land and mineral rights	2.87	2.98	-4				
Less: accumulated depreciation and depletion	41.51	40.19	3	TOTAL LIABILITIES	49.45	48.04	3
Net fixed assets	38.78	39.00	-1	Stockholders' equity			
Other assets, including investments and intangibles	22.76	21.80	4	Capital stock and other capital	14.91	13.90	2
				Retained earnings	26.72	26.92	-1
				TOTAL STOCKHOLDERS' EQUITY	41.63	40.82	2
TOTAL ASSETS	\$91.08	\$88.85	3%	TOTAL LIABILITIES AND STOCKHOLDERS' EQUITY	\$91.08	\$88.85	3%

Source: Bureau of the Census

Source: Bureau of the Census

DEBT RATIOS: Rising to relatively high levels for chemical companies

\$ Billions	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976
INDUSTRIAL CHEMICALS AND SYNTHETICS											
Long-term debt	\$20.9	\$19.2	\$18.1	\$19.4	\$22.0	\$21.4	\$16.8	\$14.8	\$13.6	\$12.3	\$11.8
Stockholders' equity	\$41.6	\$40.8	\$46.5	\$45.3	\$45.9	\$42.5	\$39.8	\$32.3	\$29.3	\$26.3	\$25.0
Debt ratio ^a	33.4%	32.0%	28.0%	30.0%	32.4%	33.5%	29.6%	31.4%	31.8%	31.9%	32.0%
CHEMICALS AND ALLIED PRODUCTS											
Long-term debt	\$45.8	\$38.2	\$33.8	\$36.2	\$38.2	\$36.9	\$26.3	\$24.9	\$23.5	\$21.1	\$19.4
Stockholders' equity	\$100.0	\$100.3	\$100.3	\$97.2	\$95.3	\$89.9	\$79.5	\$67.4	\$60.8	\$54.9	\$50.8
Debt ratio ^a	31.4%	27.6%	25.2%	27.2%	28.6%	29.1%	26.3%	27.0%	27.9%	27.8%	27.6%
ALL MANUFACTURING											
Long-term debt	\$412.2	\$367.0	\$324.2	\$286.6	\$293.1	\$266.5	\$236.2	\$204.8	\$182.0	\$167.3	\$153.6
Stockholders' equity	\$888.4	\$870.7	\$883.6	\$837.6	\$783.0	\$762.3	\$699.7	\$624.0	\$560.8	\$511.7	\$475.3
Debt ratio ^a	31.7%	29.6%	26.8%	25.5%	27.2%	25.9%	25.2%	24.7%	24.5%	24.6%	24.4%

Note: Because of changes in accounting rules and industry classifications, numbers over the entire range of years are not strictly comparable. ^a Long-term debt as a percentage of long-term debt plus stockholders' equity. Source: Bureau of the Census

CASH FLOW: Cost and revenues from restructuring have a major impact for second year in a row

\$ Millions, % of total	1986	1985	1984	1983	1982
SOURCES OF FUNDS					
Net income	\$ 3,414 13.6%	\$ 966 6.5%	\$ 3,859 29.7%	\$ 2,795 23.1%	\$ 2,750 21.4%
Depreciation and depletion	5,117 20.4	5,010 32.8	4,710 36.2	4,601 38.0	4,341 33.8
Deferred taxes	568 2.3	-34 -0.2	507 3.9	333 2.7	623 4.8
Other internal sources	6,084 24.3	6,707 43.9	2,357 18.1	2,623 21.7	2,062 16.0
Long-term debt	8,773 35.0	2,356 15.4	1,441 11.1	1,352 11.2	2,555 20.6
Stock	1,091 4.4	264 1.7	136 1.0	396 3.3	432 3.4
TOTAL	\$25,047 100.0%	\$15,289 100.0%	\$13,009 100.0%	\$12,100 100.0%	\$12,864 100.0%
APPLICATIONS OF FUNDS					
Dividends	\$ 1,992 8.0%	\$ 2,049 13.4%	\$ 1,998 15.4%	\$ 1,868 15.4%	\$ 1,791 13.9%
Capital expenditures	5,986 23.9	6,500 42.5	6,400 49.2	5,685 47.0	7,370 57.3
Additions to working capital	-567 -2.3	49 0.3	-436 -3.4	-265 -2.2	-1,402 -10.9
Reduction of long-term debt	7,669 30.6	2,555 16.7	2,529 19.4	3,249 26.9	3,592 27.9
Other applications	9,966 39.8	4,137 27.1	2,518 19.4	1,563 12.9	1,512 11.8
TOTAL	\$25,047 100.0%	\$15,289 100.0%	\$13,009 100.0%	\$12,100 100.0%	\$12,864 100.0%

Note: Data are totals for 12 major chemical producers: American Cyanamid, Dow Chemical, Du Pont, Ethyl, W. R. Grace, Hercules, Monsanto, National Distillers, Olin, Pennwalt, Rohm & Haas, and Union Carbide. Source: Company annual reports

2 Finances of the U.S. Chemical Industry

The makeup of the U.S. chemical industry has changed markedly during the past year or so. Some well-known names have exited the industry, as least as independent companies. Meanwhile, several new corporate names have appeared on the chemical scene.

The biggest name now missing from the rolls of the chemical industry is Celanese, acquired early this year for \$2.85 billion by American Hoechst, the U.S. subsidiary of West Germany's giant Hoechst Group. Last year, France's Air Liquide, to broaden its industrial gas operations in the U.S., acquired Big Three Industries for a little more than \$1 billion. At the end of the year, Sun Chemical sold off its printing inks and pigments operations to Japan's Dainippon Inks & Chemicals for \$550 million and subsequently changed its name to Sequa Corp. to mark its departure from

chemically based products. And early this year, Williams Cos. finished the disposal of its fertilizers business with the sale of its Agrico Chemical Co. to Freeport-McMoRan Resource Partners.

New players in the chemical industry that became publicly owned late last year include Aristech Chemical, formerly the USS Chemicals division of USX (formerly U.S. Steel); Vista Chemical, formed via the leveraged buyout of some of the chemical operations of the Conoco subsidiary of Du Pont; and Georgia Gulf, previously the commodity chemicals division of Georgia-Pacific. Another new kid on the block is Himont, a joint venture in polypropylene between Hercules and Italy's Montedison, that since last February has had 20% of its stock in the hands of the public.

Explanation of table headings

Year. Data are for calendar year unless otherwise indicated.

Net sales. Gross sales, less discounts, allowances, and returns; generally excludes excise taxes and other operating income or revenues.

Net income. Net sales and other income, less operating costs, nonoperating charges, depreciation, depletion, interest expense, deferred charges, minority interest in income, and taxes. Nonrecurring or extraordinary credits and charges have been excluded in most cases, but these items are indicated by a footnote.

Total assets. Sum at year's end of current assets, investments, prepaid expenses, net plant and equipment, and other tangible assets. Excludes insofar as possible intangible assets including goodwill, value of patents and trademarks, and the like.

Current ratio. The ratio of current assets (cash, marketable securities, receivables, and inven-

ories but excluding prepaid expenses) to total current liabilities.

Net plant and equipment. Value at year's end of fixed assets, less accumulated depreciation, amortization, and depletion.

Capital expenditures. Total spending during the year for new fixed assets, such as plant, equipment, and land, and for replacement and modernization of facilities.

Net worth. Equity at year's end of preferred and common stock holders, including value of capital stock, capital and earned surplus, and surplus reserves, as well as contingency and miscellaneous reserves for which no definite purpose is stated. Intangible assets are deducted insofar as possible.

Net income (breakdown). Per cent of sales: net income divided by net sales. Per cent of net worth: net income divided by tangible net worth. Dollars per share: net income, less preferred dividends,

divided by the number of shares of common stock outstanding. All figures are adjusted for stock splits, but no adjustment has been made for earlier years as a result of stock dividends or for dilution that might result from the conversion of preferred stock or debt to common stock or the exercise of stock options outstanding.

Dividends per share. Cash dividends paid (or declared) on each share of common stock; excludes the value of stock dividends, which are indicated by a footnote.

Dividend yield. Dividends per share divided by the average of the high and low prices of the common stock during the calendar year.

Stock price range. High-low market prices of common stock during the calendar year, adjusted for stock splits but not for stock dividends.

Price-earnings ratio. Average of the high and low prices of the common stock during the calendar year divided by net income per share.

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME			Dividends, \$ per share	Dividend yield, % of price	Stock price range, \$ per share	Price-earnings ratio
								% of sales	% of net worth	\$ per share				
Money figures in thousands of dollars unless otherwise indicated														
CHEMICALS														
Air Products & Chemicals														
1989 ^a	\$1,882,134	\$ 4,735 ^b	\$2,700,151	1.4	\$1,829,122	\$366,563	\$1,084,562	0.2%	0.4%	\$0.08 ^c	\$0.77	2.2%	\$41½-29½	442.2
1988 ^a	1,829,588	143,484 ^a	2,538,545	1.1	1,782,267	392,176	1,109,068	7.8	12.9	2.38 ^d	0.635	2.3	34½-22½	11.9
1984 ^a	1,735,115	140,618	2,267,457	1.1	1,587,382	262,491	1,058,328	8.1	13.3	2.28	0.525	2.5	24½-18½	9.3
1983 ^a	1,634,246	108,963	2,100,167	1.1	1,541,345	246,417	988,256	6.7	11.0	1.78	0.45	2.1	25½-17	12.0
American Cyanamid Co.														
1988	\$3,815,900	\$202,500	\$3,482,400	1.7	\$1,267,700	\$282,500	\$1,536,000	5.3%	13.2%	\$4.38	\$1.90	2.6%	\$89½-54½	16.5
1985	3,536,100	120,200 ^a	3,383,400	2.0	1,126,900	202,600	1,623,000	3.4	7.4	2.50 ^d	1.90	3.5	58½-48	21.4
1984	3,856,726	215,916	3,304,027	1.9	1,241,927	200,110	1,645,122	5.6	13.1	4.41	1.86	3.9	83½-42½	10.8
1983	3,535,514	186,356	3,031,311	2.1	1,256,658	185,068	1,578,675	4.7	10.5	3.41	1.75	3.8	58-33½	13.6
Aristech Chemical Corp.														
1989 ^a	\$ 750,800	\$ 47,000	\$ 478,100	1.9	\$ 286,300	\$ 15,800	\$ 309,700	9.3%	15.4%	\$1.70 ^f	\$0.00	0.0%	\$18½-17½	10.7
1985	739,100	20,500	452,400	2.5	303,200	17,900	262,900 ^g	2.8	7.8	0.85 ^h	—	—	—	—
1984	862,300	42,800	465,800	—	—	8,100	270,600 ^a	4.9	15.7	—	—	—	—	—
1983	899,600	2,900	465,300	—	—	—	288,400 ^a	0.4	1.0	—	—	—	—	—
Betz Laboratories														
1988	\$ 344,377	\$ 35,544	\$ 209,917	2.3	\$ 144,063	\$ 22,750	\$ 204,040	10.3%	17.4%	\$2.23	\$1.36	3.4%	\$44½-35	17.9
1985	319,581	36,782	253,704	2.2	137,255	27,030	194,760	11.5	18.9	2.33	1.26	3.7	38½-30½	14.7
1984	363,686	36,737	229,082	2.1	123,296	25,302	170,684	12.1	21.5	2.33	1.18	3.3	38-27½	14.2
1983	286,983	33,180	204,174	2.1	114,872	32,786	161,766	12.4	20.5	2.08	0.94	2.4	44½-32½	18.5

^a Fiscal year ends Sept. 30. ^b Includes special charges for writedown of assets, revaluation of South African investment, and staff reduction program of \$132.2 million (\$2.25 per share) and for loss of investment tax credits of \$7 million (\$0.13 per share). ^c Includes special charges, before taxes, of \$300,000. ^d From continuing operations; excludes net income and gain of sale of Formica Brand Products Group of \$6.9 million (\$0.16 per share). ^e Aristech Chemical, previously the USS Chemicals division of USX Corp., became an independent, publicly owned company Dec. 4. ^f Pro forma. ^g From initial public offering Dec. 4. ^h USX Corp. equity investment.

2 Finances of the U.S. Chemical Industry

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME			Dividends, \$ per share	Dividend yield, % of price	Stock price range, \$ per share	Price-earnings ratio
								% of sales	% of net worth	\$ per share				
Money figures in thousands of dollars unless otherwise indicated														
Cabot Corp.														
1986 ^a	\$ 1,309,915	\$ 33,061 ^b	\$ 1,490,759	2.0	\$ 42,137	\$ 75,551	\$ 572,145	5.6%	12.8%	\$2.56	\$0.92	3.1%	\$35½-23½	11.6
1985 ^a	1,407,516	71,290 ^a	1,573,086	1.9	623,211	141,559	604,085	5.1	11.8	2.22 ^a	0.92	3.4	33½-20½	12.2
1984 ^a	1,752,523	97,073	1,730,722	1.8	1,051,251	116,911	999,167	5.5	13.9	3.02	0.92	3.6	28½-22½	8.5
1983 ^a	1,558,016	64,162	1,290,340	2.6	656,894	76,964	658,838	4.1	9.7	2.00	0.92	3.6	30½-20½	12.8
Chemed Corp.														
1986	\$ 359,476	\$ 6,830 ^d	\$ 229,316	1.7	\$ 46,554	\$ 9,385	\$ 75,339	1.9%	9.1%	\$0.70 ^f	\$1.56	4.4%	\$ 40-30½	46.1
1985	372,677	21,858	197,615	1.7	42,092	7,874	58,234	6.6	37.5	2.40	1.52	5.1	33½-25½	11.9
1984	346,140	20,110	180,518	1.7	45,517	9,198	49,822	5.8	40.4	2.29	1.48	4.7	38½-25½	13.6
1983	271,343	17,371 ^a	174,248	1.9	35,812	5,703	58,420	6.4	29.7	2.17	1.36	3.8	39½-32	16.4
Crompton & Knowles Corp.														
1986	\$ 213,242	\$ 8,923 ^f	\$ 126,881	2.2	\$ 28,511	\$ 3,514	\$ 60,566	4.2%	14.5%	\$2.05 ^f	\$1.26	4.0%	\$30½-24½	12.0
1985	231,225	7,575	120,076	2.5	30,376	3,582	63,839	3.3	11.9	2.20	1.20	5.3	27½-18½	10.3
1984	230,434	7,891	114,135	2.5	30,809	3,917	59,586	3.4	13.2	2.31	1.14	5.3	23½-19½	9.3
1983	230,560	6,302	115,536	2.6	31,205	2,954	57,993	2.7	10.9	1.81	1.06	4.6	28½-16½	12.6
Dow Chemical Co.														
1986	\$11,113,000	\$ 741,000 ^a	\$11,939,000	1.6	\$ 5,347,000	\$ 890,000	\$ 4,865,000	6.7%	15.2%	\$3.87 ^b	\$1.85	3.8%	\$61½-39½	13.1
1985	10,500,000	58,000	11,565,000	1.5	5,127,000	806,000	4,527,000	0.6	1.3	0.31	1.80	5.2	41½-27	111.1
1984	10,679,000	549,000 ^a	11,217,000	1.5	5,173,000	781,000	4,860,000	5.1	11.3	2.63 ^a	1.80	6.0	34½-25½	10.6
1983	10,442,000	293,000 ^c	11,785,000	1.4	5,895,000	630,000	4,851,000	2.8	6.0	1.50 ^d	1.80	5.7	38½-25	21.1
E. I. du Pont de Nemours & Co.														
1986	\$27,148,000	\$1,538,000	\$26,733,000	1.5	\$15,697,000	\$2,737,000	\$13,374,000	5.7%	11.5%	\$8.35	\$3.05	4.0%	\$92½-59½	12.0
1985	29,483,000	1,118,000	25,140,000	1.6	15,195,000	3,046,000	12,659,000	3.8	8.8	4.61	3.00	5.1	89½-47½	12.7
1984	35,915,000	1,431,000	24,098,000	1.6	14,409,000	2,931,000	12,233,000	4.0	11.7	5.93	2.90	6.1	52½-42½	8.0
1983	35,378,000	1,127,000	24,432,000	1.7	14,261,000	2,628,000	11,472,000	3.2	9.8	4.70	2.50	5.5	55-35½	9.6
Essex Chemical Corp.														
1986	\$ 205,624	\$ 8,836	\$ 159,499	1.3	\$ 68,830	\$ 11,614	\$ 57,336	4.3%	15.4%	\$1.44	\$0.57	2.5%	\$29½-16	15.8
1985	190,049	8,502	140,195	2.1	64,161	8,788	50,617	4.5	18.8	1.40	0.52	3.3	19½-12½	11.3
1984	175,833	9,092 ^e	135,654	2.2	62,469	6,848	44,885	5.2	20.3	1.50	0.47	3.5	15½-10½	8.8
1983	150,509	5,639 ^a	145,011	2.3	63,448	10,711	41,690	3.7	13.5	0.92	0.42	2.7	18½-12½	16.7
Ethyl Corp.														
1986	\$ 1,579,254	\$ 177,734	\$ 1,067,825	2.1	\$ 594,238	\$ 133,700	\$ 895,790	11.3%	19.8%	\$1.40	\$0.335	1.8%	\$22½-13½	12.9
1985	1,547,834	117,148 ^f	1,509,988	2.0	557,256	80,512	754,853	7.6	15.5	0.92	0.285	2.5	15½-7½	12.6
1984	1,675,059	132,184 ^a	1,437,207	2.2	573,156	103,416	707,716	7.9	18.7	0.86	0.21	3.2	8½-5	7.7
1983	1,745,193	106,038 ^b	1,449,982	2.0	626,461	84,723	811,290	6.1	13.1	0.85	0.21	3.9	7½-3½	8.4
Ferro Corp.														
1986	\$ 725,241	\$ 24,062	\$ 443,801	1.9	\$ 153,712	\$ 23,566	\$ 217,750	3.3%	11.1%	\$3.54	\$1.20	3.4%	\$41½-30½	10.1
1985	651,071	11,163 ^a	391,133	2.0	145,651	27,050	193,850	1.7	5.8	1.60 ^a	1.28	3.9	37-24½	18.4
1984	662,867	16,886	359,938	2.0	136,462	29,364	185,983	2.5	9.1	2.53	1.20	4.0	38½-22½	12.0
1983	619,179	19,228	364,861	1.9	132,509	20,252	185,337	3.1	10.4	3.04	1.20	3.7	39½-24½	10.6
First Mississippi Corp.														
1986 ^a	\$268,898	(\$28,110) ^a	\$ 287,562	1.6	\$ 155,266	\$ 31,635	\$ 125,521	—	—	(\$1.42) ^a	\$0.24	3.8%	\$ 8½-5½	—
1985 ^a	273,185	18,239 ^b	379,587	1.5	234,574	63,257	165,339	6.7%	10.1%	0.90 ^c	0.24	2.8	11½-8½	10.1
1984 ^a	270,804	15,845 ^a	380,855	1.5	209,742	41,034	166,957	5.9	9.5	0.77 ^a	0.24	2.3	13½-7½	13.6
1983 ^a	263,976	14,146	379,438	1.2	200,990	47,428	155,055	6.9	9.1	0.69	0.24	2.0	15½-8½	17.2
GAF Corp.														
1986	\$ 753,774	\$ 80,686 ^d	\$ 1,347,069	3.9	\$ 208,396	\$ 33,914	\$ 601,496	10.7%	13.4%	\$2.22 ^e	\$0.10	0.3%	\$ 44-23½	15.3
1985	731,962	54,296 ^a	879,174	1.7	194,086	47,161	298,153	7.4	18.2	1.57 ^a	0.10	0.4	35-12½	15.0
1984	731,314	41,406 ^a	452,273	2.2	159,115	17,900	214,008	5.7	19.3	1.31 ^a	0.05	0.5	12½-7½	7.9
1983	699,397	(24,189) ^a	414,267	1.7	164,468	13,904	169,804	—	—	(1.11) ^a	0.025	0.3	9½-6½	—
W. R. Grace & Co.														
1986	\$ 3,725,700	(\$375,400) ^{a,z}	\$ 3,993,000	1.3	\$ 1,579,000	\$ 199,100	\$ 1,294,400	—	—	(\$8.94) ^{a,z}	\$2.80	5.3%	\$80½-45½	—
1985	5,153,000	127,800 ^a	5,287,800	1.9	2,596,000	348,000	2,271,400	2.5%	5.6%	2.43 ^a	2.80	6.6	49½-35½	17.3
1984	6,727,800	195,600	5,193,000	1.8	2,704,200	380,100	2,063,300	2.9	9.5	4.02	2.80	6.7	48½-36½	10.4
1983	6,219,500	159,700 ^a	4,946,800	1.8	2,715,400	353,100	2,094,300	2.6	7.6	3.28 ^a	2.80	6.3	39½-38½	13.5

a Fiscal year ends Sept. 30. b Excludes extraordinary charge for early retirement of indebtedness of \$2.0 million (\$0.07 per share). c From continuing operations; excludes net loss from discontinued operations of \$12.7 million (\$0.39 per share) and provision for net loss on disposal of discontinued operations of \$145.0 million (\$4.53 per share). d From continuing operations; excludes net income and gain on sale of discontinued Vestal Laboratories operations of \$30.0 million (\$3.36 per share) and extraordinary gain on termination of pension plan of \$611,000 (\$0.09 per share). e Excludes net gain on disposition of discontinued Dearborn Group operations of \$875,000 (\$0.11 per share). f From continuing operations; excludes net income and charge for discontinued Kern operations of \$7.9 million (\$2.48 per share). g Excludes net loss on early extinguishment of debt of \$9 million (\$0.05 per share). h Includes pretax gain on sales of investments of \$183 million but excludes tax benefit from realization of foreign tax loss carry-forwards of \$39 million (\$0.19 per share). i Includes pretax gain on sales of investments of \$101 million but excludes extraordinary net gain on debt-for-equity exchange of \$41 million (\$0.21 per share). j From continuing operations; excludes net loss from discontinued created products operations of \$2.0 million (\$0.33 per share). k From continuing operations; excludes net loss from discontinued operations of \$1.4 million (\$0.22 per share). l Includes net charges for plant shutdown and write-off costs of \$20.0 million. m Includes net nonrecurring charges of \$25.2 million. n Includes net nonrecurring charges of \$9.4 million. o Excludes net loss on sale of Product Chemical division of \$2.3 million (\$0.34 per share). p Fiscal year ends June 30. q Net loss. r Excludes net gain from disposal of FirstMiss subsidiary of \$900,000 (\$0.04 per share). s Excludes net gain from disposal of FirstMiss subsidiary of \$120,000 (\$0.01 per share). t Excludes extraordinary credits of \$212.5 million (\$5.86 per share). u Excludes extraordinary credits of \$23.3 million (\$0.68 per share). v Excludes extraordinary credits of \$15.7 million (\$0.54 per share). w Excludes extraordinary credits of \$25.4 million (\$0.68 per share). x From continuing operations; includes asset write-downs and reserves, before taxes, of \$368.8 million but excludes net loss from discontinued operations of \$96.9 million (\$2.31 per share). y From continuing operations; excludes net income from discontinued retail operations of \$19.1 million (\$0.37 per share). z Includes net gains on disposal of businesses of \$5.7 million.

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME			Dividends, \$ per share	Dividend yield, % of price	Stock price range, \$ per share	Price-earnings ratio
								% of sales	% of net worth	\$ per share				
Money figures in thousands of dollars unless otherwise indicated														
Great Lakes Chemical Corp.														
1986	\$ 300,329	\$ 26,817	\$ 447,840	2.3	\$ 209,425	\$ 18,327	\$ 172,538	8.9%	15.5%	\$1.79	\$0.52	1.4%	\$44½-30½	21.1
1985	276,932	28,818	314,423	2.2	137,710	21,344	186,716	10.4	15.4	1.93	0.44	1.2	44½-31½	19.6
1984	278,235	35,568	276,489	2.2	130,784	28,770	164,805	12.8	21.6	2.38	0.36	1.1	38½-24	13.2
1983	225,950	23,842	217,916	2.1	121,411	23,393	132,286	10.6	18.0	1.63	0.30	1.1	39½-16½	17.3
Hercules														
1986	\$2,615,110	\$226,739*	\$2,914,319	2.6	\$1,152,141	\$256,913	\$1,703,151	8.7%	13.3%	\$4.02	\$1.72	3.5%	\$80-37	12.1
1985	2,587,213	133,161*	2,658,822	2.5	1,000,212	234,240	1,474,201	5.1	9.0	2.40	1.80	4.5	40½-31½	15.9
1984	2,570,965	197,185	2,368,489	2.4	906,031	218,105	1,366,911	7.7	14.4	3.54	1.48	4.5	38-27½	9.2
1983	2,628,954	174,222	2,175,173	2.1	793,313	167,993	1,288,116	6.6	13.5	3.17	1.38	3.9	43½-27½	11.1
International Flavors & Fragrances														
1986	\$ 620,579	\$ 55,683	\$ 672,616	4.6	\$ 186,891	\$ 26,771	\$ 521,475	13.8%	16.4%	\$2.29	\$1.16	2.9%	\$48½-34½	18.2
1985	501,046	99,008	559,855	4.2	159,298	22,134	426,986	13.9	16.3	1.89	1.12	3.4	40-26	17.5
1984	476,878	68,242	452,392	4.4	140,109	29,942	351,183	14.5	19.7	1.89	1.08	4.1	29½-22½	13.8
1983	460,945	68,410	458,282	3.5	139,921	26,851	344,255	14.8	19.9	1.87	1.04	3.5	35½-23½	15.9
International Minerals & Chemical Corp.														
1986*	\$1,177,700	(\$79,600) ^a	\$2,225,200	2.2	\$2,170,700	\$ 93,900	\$ 792,400	—	—	(\$2.96) ^a	\$1.80	5.9%	\$38½-25	—
1985*	1,627,300	119,600	1,957,200	2.0	2,144,300	116,000	1,092,000	7.3%	11.0%	4.39	2.60	6.8	44-34½	8.9
1984*	1,532,900	112,000*	1,965,600	1.9	2,061,400	104,800	1,039,100	7.3	10.8	4.17*	2.60	6.4	48-32½	9.8
1983*	1,462,000	80,500	1,943,900	1.9	1,983,700	119,300	1,024,100	8.5	7.9	3.02	2.60	6.5	49-31½	13.3
Lawter International														
1986	\$ 103,515	\$ 12,945	\$ 93,392	3.7	\$ 22,447	\$ 1,613	\$ 55,191	12.5%	23.5%	\$0.74	\$0.56	3.9%	\$17½-11½	19.5
1985	96,769	5,413 ^a	84,039	3.4	22,782	3,179	47,588	—	—	(0.31) ^a	0.56	4.7	13½-10½	—
1984	96,484	14,862	77,577	4.8	21,146	3,339	58,370	15.1	25.5	0.96	0.55	4.4	14½-10½	14.5
1983	90,620	14,340	75,615	4.4	21,066	3,345	55,785	18.9	25.7	0.83	0.49	4.6	14½-7½	12.8
Liquid Air Corp.														
1986	\$ 570,565	\$ 34,680	\$ 682,307	1.1	\$ 475,321	\$130,544	\$ 303,554	6.1%	11.4%	\$2.42	\$1.80	5.1%	\$38½-25½	12.9
1985	543,041	31,753	599,281	1.2	418,165	103,675	289,819	5.8	11.0	2.42	1.80	6.8	27½-19½	9.8
1984	501,735	27,304	548,821	1.8	379,530	62,461	246,867	5.4	11.1	2.07	1.80	7.7	23-18½	18.0
1983	459,409	23,902	500,573	1.5	354,796	41,620	244,849	5.2	9.8	1.80	1.80	7.2	26½-18½	12.4
Locitile Corp.														
1986*	\$ 266,788	\$ 23,173	\$ 240,665	2.2	\$ 57,711	\$ 9,290	\$ 150,183	8.7%	15.4%	\$2.56	\$0.82	2.0%	\$49½-33½	16.2
1985*	231,479	20,443	215,482	1.9	49,793	11,278	121,918	8.8	16.8	2.24	0.80	2.5	37-27	14.3
1984*	241,744	26,349	223,694	2.0	45,996	6,172	120,526	10.9	20.3	2.67	0.84	1.7	42½-30½	13.7
1983*	215,892	17,128	209,387	2.2	46,789	9,955	129,419	7.9	13.2	1.72	0.56	1.5	46½-28½	21.8
Lubrizol Corp.														
1986	\$ 976,776	\$ 78,185	\$ 877,907	2.7	\$ 299,078	\$ 40,480	\$ 572,679	8.0%	13.7%	\$1.97	\$1.17	3.9%	\$35½-25½	16.4
1985	903,403	60,224	854,445	2.4	290,298	39,498	519,298	6.7	11.5	1.49	1.16	4.8	28½-19½	16.3
1984	831,661	67,731	781,974	2.8	251,735	29,490	474,343	8.1	14.3	1.73	1.12	5.2	24½-18½	12.4
1983	789,546	64,744*	662,864	2.8	274,337	25,093	471,521	8.2	13.7	1.65*	1.08	4.7	27½-18½	13.9
Monsanto Co.														
1986	\$6,879,000	\$433,000	\$6,125,000	1.4	\$2,913,000	\$520,000	\$1,837,000	6.3%	26.5%	\$5.55	\$2,575	4.1%	\$81½-44½	11.4
1985	6,747,000	(128,000) ^h	6,678,000	1.1	3,034,000	645,000	1,208,000	—	—	(1.87) ^h	2.45	5.1	55½-40½	—
1984	6,991,000	439,000	6,250,000	2.0	3,374,000	614,000	3,511,000	6.8	12.5	5.42	2.25	4.8	53½-40½	11.5
1983	6,299,000	369,000*	6,427,000	2.1	3,284,000	560,000	3,667,000	5.9	10.1	4.48*	2,075	4.4	58½-37½	18.6
Morton Thiokol														
1986*	\$1,949,900	\$132,900	\$1,225,000	1.7	\$ 583,900	\$ 95,700	\$ 629,900	6.8%	21.1%	\$2.80	\$0.685	1.9%	\$42½-30	12.9
1985*	1,832,300	119,500*	1,173,900	1.8	560,700	117,000	510,500	6.5	23.4	2.44*	0.83	1.9	40½-26	13.6
1984*	2,001,500	109,750	1,152,082	1.5	526,713	90,859	489,145	5.5	22.4	2.17	0.57	2.2	31½-20	11.9
1983*	1,590,157	78,462	1,002,848	1.3	522,938	76,944	461,952	5.2	19.5	1.72	0.83	2.4	28½-18½	12.6
Nalco Chemical Co.														
1986	\$ 736,074	\$ 63,672	\$ 536,916	1.7	\$ 280,195	\$ 63,636	\$ 358,023	8.7%	17.8%	\$1.62	\$1.20	4.4%	\$31½-23½	16.9
1985	682,333	73,332	492,998	1.8	247,912	59,905	335,885	10.7	21.8	1.87	1.20	4.8	28½-22	13.5
1984	664,303	73,089*	471,543	2.4	205,103	52,478	344,392	11.0	21.2	1.80*	1.20	4.4	33½-21	14.8
1983	658,403	71,000	487,010	2.3	191,791	40,505	348,386	10.8	20.4	1.78	1.14	3.5	37-28	18.3
National Distillers & Chemical Corp.														
1986	\$1,729,900	\$ 55,100*	\$2,844,200	1.0	\$1,383,800	\$101,600	\$ 944,500	3.2%	5.9%	\$1.54*	\$2.29	5.5%	\$47½-33	26.2
1985	2,280,000	77,000*	1,948,000	1.5	899,300	76,200	930,300	3.4	8.3	2.27*	2.29	7.2	37½-23½	13.5
1984	2,244,900	89,900*	1,828,800	1.9	747,700	116,100	943,500	3.1	7.4	2.01*	2.20	8.3	36-22½	13.1
1983	2,588,900	96,700	1,907,300	2.3	789,900	71,300	1,032,300	2.6	6.5	1.77	2.29	8.0	31-23½	15.5

a Includes pretax gain on disposal of assets of \$77.4 million. b Includes pretax gain on disposal of assets of \$16.4 million. c Fiscal year ends June 30. d Net loss. e From continuing operations; excludes net loss from operations and net provision for loss on disposal of discontinued gas and oil and industrial products operations of \$137.4 million (\$5.08 per share). f Excludes net loss from operations and disposal of discontinued methanol joint venture of \$30.3 million (\$1.13 per share). g Includes one-time tax provision for future repatriation of foreign earnings of \$14.0 million (\$0.80 per share). h Includes net gain on sale of investments of \$7.5 million (\$0.19 per share). i Includes special charge for restructuring costs, before taxes, of \$557 million but excludes net gain from repayment of debt of \$30 million (\$0.40 per share). j Excludes extraordinary net tax benefits from utilization of ex-U.S. loss carry-forwards of \$33 million (\$0.41 per share). k From continuing operations; excludes net income from discontinued Texsize division operations of \$3.3 million (\$0.06 per share) and net gain on sale of the division of \$75.1 million (\$1.51 per share). l Excludes net income from discontinued lead antiknock compounds operations of \$3.1 million (\$0.08 per share). m From continuing operations; excludes net income from discontinued spirits and wine operations of \$20.5 million (\$0.67 per share). n From continuing operations; excludes net income from discontinued insurance business of \$200,000 (\$0.01 per share). o From continuing operations; excludes net loss from discontinued metals and petroleum operations of \$18.5 million (\$0.60 per share).

2 Finances of the U.S. Chemical Industry

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME			Dividends, \$ per share	Dividend yield, % of price	Stock price range, \$ per share	Price-earnings ratio
								% of sales	% of net worth	\$ per share				
Money figures in thousands of dollars unless otherwise indicated														
Olin Corp.														
1986	\$1,707,261	\$ 75,226	\$ 1,464,830	1.5	\$ 719,686	\$127,935	\$ 574,290	4.4%	13.1%	\$3.36	\$1,525	3.5%	\$53½-34½	13.1
1985	1,751,106	(190,308) ^a	1,516,096	1.6	718,371	154,499	604,844	—	—	(8.28) ^a	1.50	4.5	38-28½	—
1984	2,065,328	88,747	1,822,099	1.5	860,658	165,000	867,307	4.3	10.2	3.81	1,355	4.7	33½-25½	7.7
1983	1,934,579	71,715	1,829,416	1.9	850,936	122,580	848,355	3.7	8.5	3.01	1.23	4.3	34-23	9.5
Pennwalt Corp.														
1986	\$1,107,584	\$ 51,947	\$ 962,252	2.1	\$ 436,282	\$ 54,379	\$ 465,369	4.7%	11.2%	\$3.64	\$2.20	4.4%	\$ 58-40½	13.7
1985	1,013,308	11,218 ^b	937,672	1.5	433,867	89,691	445,020	1.1	2.5	0.05 ^c	2.20	5.6	44½-34	785.0
1984	1,047,214	45,356	868,673	1.9	393,765	87,177	485,325	4.3	9.3	3.31	2.20	6.0	42½-31½	11.1
1983	976,741	44,798 ^d	851,982	2.6	348,190	69,808	456,077	4.6	9.8	3.58 ^d	2.20	5.9	45½-29	10.4
Reichhold Chemicals														
1986	\$ 765,588	\$ 15,859 ^e	\$ 426,301	1.4	\$ 202,988	\$ 40,912	\$ 163,942	2.1%	9.7%	\$2.13 ^e	\$0.80	2.4%	\$38½-28½	15.6
1985	822,534	(28,432) ^f	451,903	1.2	203,972	35,057	134,714	—	—	(3.85) ^f	0.80	2.2	43½-29½	—
1984	801,355	25,709	371,819	2.0	172,219	24,228	206,421	3.2	12.5	3.63	0.85	2.2	35½-23	7.5
1983	747,263	21,700	382,273	2.0	175,722	19,305	211,081	2.9	10.3	2.74	0.51	1.8	38½-18½	10.4
Rohm & Haas Co.														
1986	\$2,067,000	\$138,900 ^g	\$ 1,756,000	2.0	\$ 648,000	\$179,000	\$ 916,000	6.7%	15.1%	\$2.01 ^g	\$0.78	2.5%	\$38½-23½	15.6
1985	2,051,000	141,000 ^h	1,655,000	2.0	581,000	159,000	857,000	6.9	16.5	2.01 ^h	0.70	3.1	26½-18½	11.1
1984	2,042,011	172,219 ⁱ	1,540,570	2.0	555,945	134,253	872,687	8.4	19.7	2.24 ⁱ	0.60	3.1	23½-16	8.7
1983	1,875,937	137,603	1,489,815	2.7	518,360	71,534	882,964	7.3	16.6	1.78	0.50	2.5	27-12½	11.1
Sigma-Aldrich Corp.														
1986	\$ 253,097	\$ 33,958	\$ 244,875	2.5	\$ 86,111	\$ 35,461	\$ 155,689	13.4%	21.8%	\$1.38	\$0.25	0.7%	\$40½-26½	24.3
1985	214,848	28,835	186,552	3.4	57,771	17,386	126,306	13.4	22.9	1.13	0.21	0.9	28½-17½	20.1
1984	179,529	24,220	174,144	5.4	46,037	11,852	129,932	13.5	18.6	0.93	0.175	1.1	17½-14½	16.9
1983	150,592	19,715	140,506	5.8	39,050	7,882	109,842	13.1	17.9	0.76	0.15	1.0	17½-12½	19.7
Stepan Co.														
1986	\$ 259,787	\$ 7,513	\$ 152,794	1.5	\$ 85,607	\$ 14,322	\$ 55,029	2.9%	13.6%	\$2.53	\$0.74	2.6%	\$35½-20½	11.3
1985	235,919	5,471	139,307	1.5	82,796	19,189	49,575	2.3	11.0	1.89	0.69	3.5	23½-16½	10.5
1984	234,930	5,423 ^j	133,941	1.6	73,261	11,557	47,660	2.3	11.4	1.66 ^j	0.65	3.9	18½-14½	10.0
1983	207,074	6,337	144,967	1.5	76,044	9,804	58,459	3.1	19.8	1.75	0.58	3.9	17½-12	8.4
Union Carbide Corp.														
1986	\$6,244,000	\$130,000 ^k	\$ 7,496,000	1.2	\$4,375,000	\$524,000	\$ 930,000	2.1%	14.0%	\$1.25	\$1.50	5.8%	\$33½-18½	20.8
1985 ^l	5,596,000	(38,000) ^m	8,461,000	1.3	4,927,000	649,000	519,000	—	—	(0.38) ⁿ	1.13	6.1	24½-12	—
1984	9,508,000	341,000 ^o	10,402,000	1.8	6,383,000	670,000	4,808,000	3.6	7.1	1.61 ^o	1.13	6.9	21½-10½	10.1
1983	9,001,000	218,000 ^p	10,226,000	1.8	6,282,000	761,000	4,860,000	2.4	4.5	1.04 ^p	1.13	5.4	24½-17	20.1
Vista Chemical Corp.														
1986 ^q	\$ 550,097	\$ 30,212 ^r	\$ 453,418	1.8	\$ 272,699	\$ 15,792	\$ 60,808	5.5%	49.7%	\$1.73	\$0.00	0.0%	\$18½-17½	10.3
1985 ^s	521,313	11,917	454,688	1.9	262,946	10,284	23,281	2.3	51.2	0.68	0.00	0.0	—	—
1984 ^t	101,122	2,006	536,102	—	—	1,596	—	2.0	—	0.12	0.00	0.0	—	—
1983	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Witco Corp.														
1986	\$1,355,018	\$ 65,215	\$ 804,086	2.4	\$ 367,789	\$ 60,102	\$ 449,783	4.8%	14.5%	\$2.93	\$1.05	3.2%	\$ 40-20½	11.3
1985	1,448,929	56,774	794,368	2.3	300,950	71,093	399,486	3.9	14.2	2.57	0.99	4.0	27½-22	9.7
1984	1,495,831	62,602	739,488	2.2	348,740	65,720	358,497	4.2	17.5	2.85	0.93	4.2	26½-18½	7.8
1983	1,305,744	52,622	715,472	2.1	313,794	44,901	319,334	3.8	16.3	2.40	0.84	4.6	24½-11½	7.8
PHARMACEUTICALS														
Abbott Laboratories														
1986	\$3,807,534	\$540,460	\$ 3,865,609	1.3	\$1,543,267	\$383,400	\$1,778,921	14.2%	30.4%	\$2.32	\$0.84	1.9%	\$ 55-31½	19.7
1985	3,360,273	465,335	3,468,373	1.9	1,368,542	292,900	1,870,863	13.8	24.9	1.94	0.70	2.5	36-19½	14.4
1984	3,103,982	402,575	3,172,997	1.7	1,236,572	334,800	1,602,700	13.0	25.1	1.67	0.60	2.8	24½-18½	12.8
1983	2,927,873	347,617	2,824,126	1.7	1,069,200	311,800	1,417,883	11.9	24.5	1.43	0.50	2.2	26½-18	15.6
American Home Products Corp.														
1986	\$4,826,512	\$778,824	\$ 3,819,146	2.7	\$ 929,400	\$204,764	\$2,024,869	15.8%	38.5%	\$5.18	\$3.10	4.0%	\$94½-61½	15.1
1985	4,694,742	717,140	3,201,746	3.3	859,414	179,347	2,098,293	15.3	34.2	4.70	2.90	5.0	86½-50½	12.4
1984	4,495,470	655,829 ^u	2,849,732	3.3	769,623	141,891	1,905,733	14.6	34.4	4.26 ^v	2.64	5.2	55½-46½	12.0
1983	4,856,501	627,233	2,864,104	2.9	812,370	204,680	1,826,984	12.9	34.3	4.00	2.40	5.0	54½-41½	12.0

^a Net loss. ^b From continuing operations; includes special charge for restructuring costs, before taxes, of \$330.0 million but excludes net income and net gain on sale of Ecusta paper and film businesses of \$25.0 million (\$1.09 per share). ^c From continuing operations; includes special charge for restructuring program, before taxes, of \$38.6 million but excludes net loss from operations and on disposal of discontinued dental businesses of \$30.9 million (\$2.90 per share). ^d Includes gain on sale, retirement, and revaluation of assets, before taxes, of \$21.7 million. ^e Includes net gain on sale or liquidation of assets of \$14.6 million. ^f Includes special charge for restructuring program, before taxes, of \$39.6 million. ^g Includes net loss on disposal of assets of \$9.2 million (\$0.13 per share). ^h Includes net gain on disposal of assets of \$4.6 million (\$0.07 per share). ⁱ Includes net loss on sale of oil and gas properties of \$3.6 million (\$0.05 per share). ^j Includes nonrecurring net loss on write-down of equipment of \$2.6 million. ^k From continuing operations; excludes net income and net gain on disposals of discontinued operations of \$569 million (\$5.49 per share) and net charges for extraordinary items of \$203 million (\$1.99 per share). ^l Pro forma, after adjustment for repurchase of common stock, sale of consumer products businesses, special charges for restructuring program, and other special gains and losses. ^m Excludes extraordinary charge related to accident in Bhopal, India, of \$16 million (\$0.08 per share). ⁿ Excludes nonrecurring net charge for closing of facilities of \$139 million (\$0.66 per share). ^o Fiscal year ends Sept. 30. ^p Excludes net loss on extinguishment of debt of \$1.4 million (\$0.08 per share). ^q From initial public offering Dec. 11. ^r From start of operations July 20. ^s From continuing operations; excludes net income from operations and net gain on sale of discontinued businesses of \$76.3 million (\$0.50 per share).

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME			Dividends, \$ per share	Dividend yield, % of price	Stock price range, \$ per share	Price-earnings ratio
								% of sales	% of net worth	\$ per share				
Money figures in thousands of dollars unless otherwise indicated														
Bristol-Myers Co.														
1986	\$4,835,900	\$589,500	\$3,993,900	2.5	\$1,070,000	\$221,900	\$2,646,500	12.2%	22.3%	\$ 2.08	\$1.06	2.9%	\$ 44½-30½	18.0
1985	4,444,000	531,400	3,557,300	2.3	925,900	222,000	2,287,100	12.0	23.2	1.93	0.905	3.1	34½-24½	15.2
1984	4,189,400	472,400	3,100,900	2.4	791,100	191,000	1,998,100	11.3	23.6	1.72	0.75	3.2	29½-20½	13.6
1983	3,917,000	408,000	2,888,300	2.2	701,700	165,000	1,788,900	10.4	22.8	1.50	0.58	2.9	24-15½	13.2
Eli Lilly & Co.														
1986	\$3,720,400	\$550,200	\$4,117,000	1.7	\$1,527,900	\$283,000	\$2,260,900	15.0%	24.7%	\$ 4.81	\$1.80	2.7%	\$ 83½-50½	18.7
1985	3,270,800	517,600	3,859,400	1.7	1,374,000	207,100	2,293,400	15.8	22.8	3.88	1.80	3.8	55½-32½	11.9
1984	3,109,200	490,200	3,556,500	1.6	1,280,400	205,300	2,133,900	15.8	23.0	3.36	1.49	4.9	33½-26½	9.0
1983	3,033,700	457,400	3,401,200	1.7	1,212,600	199,900	2,106,400	15.1	21.6	3.06	1.375	4.4	34½-28½	10.2
Merck & Co.														
1986	\$4,128,900	\$675,700	\$4,967,900	1.7	\$1,906,200	\$210,600	\$2,431,900	16.4%	27.8%	\$ 4.85	\$1.90	1.9%	\$129½-67½	20.3
1985	3,547,500	539,900	4,805,100	1.9	1,882,900	237,000	2,536,900	15.2	21.3	3.79	1.80	2.8	88½-45½	15.0
1984	3,559,865	492,967	4,489,687	1.9	1,912,778	274,425	2,443,260	13.8	20.2	3.35	1.50	3.4	48½-39½	13.1
1983	3,246,139	450,855	4,119,098	1.7	1,715,207	272,750	2,339,013	13.9	19.3	3.05	1.40	3.0	52½-40½	15.3
Pfizer														
1986	\$4,476,900	\$880,000	\$4,946,700	1.9	\$1,351,300	\$196,100	\$3,196,200	14.7%	20.6%	\$ 3.90	\$1.64	2.8%	\$ 72½-46½	15.3
1985	4,024,500	579,700	4,341,500	2.1	1,288,300	195,800	2,805,900	14.4	20.7	3.44	1.48	3.2	56½-37½	13.6
1984	3,854,500	507,900	3,927,700	2.1	1,155,500	144,000	2,365,100	13.2	21.5	3.08	1.32	3.7	42½-29½	11.6
1983	3,750,000	447,100	3,830,000	2.0	1,157,000	214,900	2,674,700	11.9	21.6	2.73	1.16	3.0	44½-33½	14.4
A. H. Robins Co.														
1986	\$ 789,895	\$ 81,796	\$ 752,230	3.5	\$ 137,984	\$ 13,590	(\$37,532) ^a	10.4%	—	\$ 3.38	\$0.00	0.0%	\$ 15½-7½	3.4
1985	708,134	61,414 ^b	620,710	3.7	149,954	23,150	(132,933) ^a	8.7	—	2.53 ^b	0.00	0.0	24½-5½	5.9
1984	631,891	(461,613) ^c	595,627	1.5	135,585	38,155	(210,353) ^a	—	—	(18.44) ^a	0.72	4.1	23½-12½	—
1983	563,510	58,221 ^d	459,462	3.1	107,951	20,955	305,638	10.3	19.0%	2.40	0.62	2.7	29½-16	9.5
Schering-Plough Corp.														
1986	\$2,398,700	\$205,800	\$2,862,000	1.3	\$1,143,500	\$124,800	\$1,319,700	11.1%	20.1%	\$ 2.17	\$0.90	2.5%	\$ 44-28	16.6
1985	1,927,100	192,600	2,683,800	1.4	991,900	140,300	1,389,800	10.0	13.9	1.88	0.84	3.3	33½-17½	13.5
1984	1,874,300	177,200	2,436,200	1.2	912,400	173,700	1,235,100	9.5	14.3	1.75	0.84	4.6	20-16½	10.4
1983	1,808,500	178,500 ^e	2,308,800	1.3	841,400	177,700	1,186,500	9.9	15.0	1.70 ^f	0.84	4.0	24-18½	12.5
SmithKline Beckman Corp.														
1986	\$3,745,400	\$521,100	\$3,691,400	1.3	\$1,410,800	\$237,000	\$ 965,400	13.9%	54.0%	\$ 3.39	\$1.50	3.4%	\$ 52½-36½	13.2
1985	3,256,800	514,400	3,534,500	1.8	1,285,300	248,000	2,070,100	15.8	24.8	3.28	1.425	4.3	39½-26½	10.1
1984	2,949,200	500,300 ^g	3,077,600	2.0	1,093,000	241,500	1,952,100	17.0	25.6	3.10 ^h	1.40	5.1	30½-25	8.9
1983	2,635,391	485,990 ⁱ	3,085,400	1.8	988,857	232,914	1,970,793	17.1	24.7	2.92 ^j	1.325	4.0	38½-27½	11.3
Squibb Corp.														
1986	\$1,784,629	\$263,639 ^k	\$2,408,831	1.8	\$ 645,630	\$ 95,077	\$1,358,098	14.8%	19.4%	\$ 2.45 ^l	\$0.97	1.9%	\$ 82-38½	20.4
1985	2,041,745	226,599	2,396,592	2.0	701,439	120,342	1,409,382	11.1	16.1	2.10	0.86	2.6	41½-24½	15.7
1984	1,888,637	197,172	2,072,188	2.1	617,724	115,629	1,286,517	10.5	15.8	1.84	0.74	3.2	27½-19½	12.5
1983	1,768,891	173,274 ^m	1,887,783	2.2	564,613	109,900	1,173,399	9.6	14.8	1.65 ⁿ	0.68	2.8	27½-21½	14.9
Sterling Drug														
1986	\$1,990,434	\$171,507	\$1,624,545	2.1	\$ 397,156	\$ 67,881	\$ 874,312	8.8%	19.8%	\$ 2.91	\$1.29	2.9%	\$ 52-36½	15.2
1985	1,753,724	153,310 ^o	1,588,991	2.0	358,190	74,176	907,046	8.7	16.9	2.50 ^p	1.19	3.5	41½-26½	13.3
1984	1,827,295	144,853 ^q	1,429,618	2.5	370,273	73,159	894,943	7.9	16.2	2.39 ^r	1.15	4.3	30-23½	11.2
1983	1,901,171	136,844	1,437,440	2.5	386,328	63,189	879,655	7.2	15.6	2.24	1.11	4.3	29½-22½	11.6
Upjohn Co.														
1986	\$2,280,325	\$252,648	\$2,684,956	1.9	\$ 981,540	\$201,920	\$1,470,216	11.1%	17.2%	\$ 1.35	\$0.51	1.9%	\$ 35½-20½	20.7
1985	2,009,486	203,193 ^s	2,376,873	1.8	852,054	152,637	1,295,085	10.1	15.7	1.10 ^t	0.45	2.6	23½-11½	15.8
1984	2,179,060	173,272	2,248,363	1.5	909,534	136,738	1,134,154	8.0	15.3	0.94	0.43	4.4	12-7½	10.3
1983	1,986,106	180,225	2,195,048	1.9	754,954	155,016	1,067,288	8.1	15.2	0.88	0.39	4.1	11½-7½	10.9
Warner-Lambert Co.														
1986	\$3,182,918	\$291,784 ^u	\$2,479,054	1.4	\$ 819,291	\$137,996	\$ 870,453	8.4%	30.1%	\$ 3.54 ^v	\$1.50	2.9%	\$ 63½-45	15.3
1985	3,200,990	237,704 ^w	2,296,187	1.2	868,931	138,774	816,279	7.4	29.0	3.05 ^x	1.50	3.2	49½-33½	13.8
1984	3,186,657	223,887	2,377,098	1.5	863,179	142,461	910,125	7.1	24.6	2.81	1.48	4.6	36½-28½	11.5
1983	3,108,325	200,496	2,388,879	1.7	826,232	165,554	889,980	6.5	23.0	2.51	1.42	4.7	38-25½	12.1

^a Deficit. ^b Excludes extraordinary net gain from tax benefit associated with operating carry-forward of \$14.4 million (\$0.59 per share). ^c Net loss; includes income, before taxes, from litigation settlement of \$1.2 million and net charge for reserve for Dalkon Shield claims of \$469.1 million (\$19.53 per share). ^d Includes net income, before taxes, from litigation settlement of \$2.3 million. ^e From continuing operations; excludes net gain on sale of discontinued home products business of \$11.6 million (\$0.11 per share). ^f Excludes net gain on sale of Industrial Business Group of \$3.3 million (\$0.02 per share). ^g From continuing operations; excludes net income of discontinued Industrial Business Group of \$3.5 million (\$0.02 per share). ^h From continuing operations; excludes net income from discontinued operations of \$13.1 million (\$0.12 per share). ⁱ Net gain on disposal of discontinued operations of \$167.6 million (\$1.75 per share), and extraordinary net charge for write-off of certain foreign assets of \$88.9 million (\$0.83 per share). ^j Excludes extraordinary net gain on early extinguishment of debt of \$27.0 million (\$0.26 per share) and net loss on disposal of Latin American operations of \$27.6 million (\$0.27 per share). ^k From continuing operations; excludes net loss from divested Hilton-Davies chemical business of \$43.6 million (\$0.73 per share). ^l From continuing operations; excludes net loss on operations of divested environmental control business of \$1.5 million (\$0.02 per share). ^m From continuing operations; excludes net loss from operations and sale of polymer chemical business of \$236,000. ⁿ Excludes net nonrecurring credit from write-down and divestiture of assets and restructuring program of \$47.7 million (\$0.64 per share). ^o Excludes net nonrecurring charge for write-down and divestiture of assets and restructuring program of \$553.3 million (\$7.10 per share).

3 Employment in the U.S. Chemical Industry

Chemical employment continues to dwindle

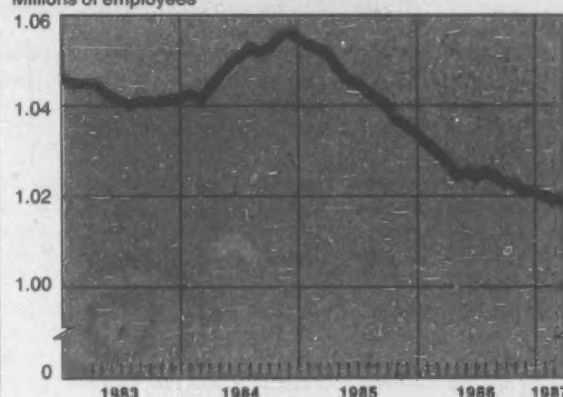
The number of workers employed by the U.S. chemical industry declined again in 1986 to about 1,027,000, the lowest level since 1975. The size of the chemical work force has been shrinking steadily since the end of 1984, and the downward pattern continues in the first half of 1987.

Only one chemical sector of the overall chemical industry—drugs—had more employees in 1986. Yet those additions returned the drug work force only to its 1984 levels. Producers of inorganic and organic chemicals and plastics made the deepest cuts in employee rolls.

Major chemical firms as a group reduced their ranks of employees by a whopping 24%. W. R. Grace and Union Carbide accounted for most of the decline, as both firms sold major operating units during the past year. However, such other large employers as Monsanto and Dow Chemical also trimmed employment significantly.

Employment in chemical industry dropped more than 3% in 1985 and 1986

Millions of employees^a



^a Seasonally adjusted employment in U.S. chemicals and allied products industry; March and April 1987 figures are preliminary. Source: Department of Labor

INDUSTRIAL EMPLOYMENT: Long-term decline continues in chemical industry

	All employees ^a (thousands)				Production workers ^a (thousands)				Workweek ^{a,b} (hours)			
	1986	1985	1984	1976	1986	1985	1984	1976	1986	1985	1984	1976
All manufacturing	19,186	19,314	19,378	18,997	13,023	13,130	13,285	13,638	40.7	40.5	40.7	40.1
Chemicals and allied products	1,027	1,046	1,049	1,042	572	579	583	600	42.0	41.9	41.9	41.8
Industrial inorganic chemicals	137	143	143	152	70	72	73	93	42.1	41.7	42.1	41.8
Plastic materials and synthetics	167	172	178	218	112	114	117	141	42.2	42.3	42.2	41.5
Drugs	206	205	206	171	96	95	96	85	41.6	41.1	40.7	40.9
Soap, cleaners, and toilet goods	147	148	145	128	93	94	93	77	41.0	41.0	41.3	40.9
Paints and allied products	63	64	62	65	31	31	30	35	41.8	41.4	41.7	41.2
Industrial organic chemicals	155	160	162	159	82	82	82	80	43.5	43.3	43.0	42.6
Agricultural chemicals	57	60	61	67	35	37	38	42	42.3	42.7	42.8	43.0
Miscellaneous chemical products	94	95	92	82	53	54	54	47	41.8	41.9	41.8	41.3
Petroleum and coal products	164	176	189	199	103	107	111	128	43.7	43.0	43.7	42.1
Rubber and miscellaneous plastics products	801	790	730	640	624	610	608	493	41.3	41.1	41.7	40.7

^a Domestic employment. ^b Workweek of production or nonsupervisory workers. Source: Department of Labor

EMPLOYMENT OF SCIENTISTS, ENGINEERS: Large increase in pharmaceutical sector

Thousands ^a	1986 ^b	1985 ^b	1984	1983	1982	1981	1980	1979	1978	1977	1976
Total, all industry	580.2	563.9	544.5	522.1	509.8	487.8	450.6	423.9	404.4	382.8	364.4
Chemicals and allied products	71.3	67.0	67.1	66.0	61.6	54.7	51.4	50.0	48.3	46.4	44.4
Industrial chemicals	26.8	25.0	26.7	27.2	25.9	21.6	20.9	21.4	21.3	20.6	20.1
Drugs and medicines	33.3	30.7 ^c	30.1 ^c	28.2	25.6	23.3	21.6	20.8	19.5	17.8	16.6
Other chemicals	11.2	11.3	10.3	10.6	10.1	9.8	8.9	7.8	7.5	8.0	7.8
Petroleum refining	10.3	13.4	13.2	14.7	15.6	13.0	10.8	10.1	9.9	8.9	8.6
Rubber products	13.2	13.4	na	na	8.1	10.3	na	8.1	7.9	9.1	8.6

^a Full-time equivalent number of R&D scientists and engineers in industry, as of January of each year. ^b Preliminary. ^c Partly estimated. na = not available separately, but included in total. Source: National Science Foundation

CHEMICAL EMPLOYMENT: Down dramatically last year following divestitures and restructuring

Thousands	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976
Air Products	16.6	18.7	17.7	16.7	18.9	18.2	15.8	14.6	14.3	13.7	13.4
American Cyanamid	34.5	36.4	38.2	38.7	40.2	41.8	42.6	44.2	44.0	43.8	39.4
Crompton & Knowles	1.3	2.3	2.3	2.4	2.3	2.5	2.8	3.0	3.2	3.1	3.0
Dow Chemical	51.3	53.2	49.8	54.5	56.6	63.8	58.8	55.9	53.5	53.2	53.0
Ethyl	10.5	10.5	11.0	13.0	14.0	14.5	15.0	16.0	16.5	16.0	16.0
H. B. Fuller	4.5	4.4	4.3	4.1	4.0	3.3	3.4	3.4	3.3	3.0	2.8
W. R. Grace	41.4	116.9	102.6	95.5	82.2	89.0	92.0	82.8	89.1	69.1	64.0
Hercules	25.1	25.4	26.3	24.2	24.5	25.9	26.1	27.4	27.1	26.3	25.7
International Flavors	3.6	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.5	3.3	3.1
International Minerals	13.9	8.7	9.0	8.4	8.4	10.6	10.6	10.3	9.9	9.9	9.7
Lubrizol	4.8	5.2	4.2	4.2	4.3	4.2	4.2	3.9	3.8	3.8	3.6
Monsanto	51.7	56.1	50.8	48.8	52.2	57.4	61.8	63.9	62.9	61.5	61.9
Nalco Chemical	4.9	5.1	4.8	4.6	4.6	4.7	4.3	4.1	4.1	4.2	3.8
Olin	13.2	14.9	17.8	18.2	17.5	20.3	21.0	21.7	22.7	22.4	22.0
Pennwalt	9.6	9.9	9.8	9.8	9.5	10.7	12.8	13.3	14.0	13.9	13.9
PPG Industries	36.5	37.5	37.7	37.0	37.0	36.6	37.3	38.2	37.4	36.6	36.3
Reichhold Chemicals	4.0	4.6	4.2	4.4	4.5	5.6	5.6	6.4	6.5	6.5	5.8
Rohm & Haas	12.1	11.8	11.9	11.4	11.5	13.5	13.2	13.3	13.1	13.0	13.3
Stepan	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.9	0.8	0.8	0.7
Union Carbide	50.3	91.5	98.4	99.5	103.2	110.3	116.1	115.8	113.4	113.7	113.1
TOTAL EMPLOYEES	390.8	517.7	505.4	500.0	499.9	535.4	545.8	542.7	523.1	517.6	504.5
ANNUAL CHANGE	-24.5%	2.4%	1.1%	0.0%	-6.6%	-1.9%	0.6%	3.7%	1.1%	2.6%	2.2%
SALES PER EMPLOYEE	\$135.2	\$113.4	\$115.4	\$109.8	\$107.6	\$109.3	\$102.2	\$ 93.6	\$ 80.9	\$ 74.0	\$ 68.9
(\$ thousands, current)											
SALES PER EMPLOYEE	\$ 46.9	\$ 39.0	\$ 39.9	\$ 39.1	\$ 38.3	\$ 39.6	\$ 40.9	\$ 43.9	\$ 42.4	\$ 40.0	\$ 38.9
(\$ thousands, constant 1972*)											

Note: Data are not restated for acquisitions, divestitures, and similar developments. * Based on producer price index for chemicals and allied products.

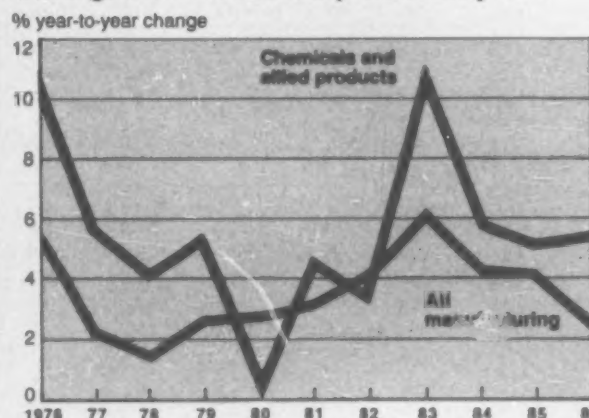
WAGES: Twice the level of a decade ago for chemical workers

	Hourly earnings*				Weekly earnings*			
	1986	1985	1984	1976	1986	1985	1984	1976
All manufacturing	\$ 9.73	\$ 9.53	\$ 9.18	\$5.22	\$396.01	\$385.97	\$373.63	\$209.32
Chemicals and allied products	11.97	11.56	11.08	5.91	502.74	484.36	464.25	245.86
Industrial inorganic chemicals	13.14	12.81	12.30	6.37	553.19	534.18	517.83	286.27
Plastic materials and synthetics	12.10	11.71	11.10	5.79	510.62	495.33	468.42	240.29
Drugs	11.12	10.74	10.23	5.59	462.59	441.41	416.36	228.63
Soap, cleaners, and toilet goods	10.73	10.27	9.89	5.59	439.93	421.07	408.46	228.63
Paints and allied products	10.42	10.08	9.75	5.43	433.47	417.31	406.58	223.72
Industrial organic chemicals	14.36	13.98	13.43	6.88	624.66	605.33	577.49	293.09
Agricultural chemicals	11.42	11.02	10.73	5.44	483.07	470.55	459.24	233.92
Miscellaneous chemical products	11.15	10.61	10.08	5.54	466.07	444.58	421.34	228.80
Petroleum and coal products	14.19	14.06	13.43	7.21	620.10	604.58	586.89	303.54
Rubber and miscellaneous plastic products	8.76	8.54	8.29	4.66	361.79	350.99	345.69	189.66

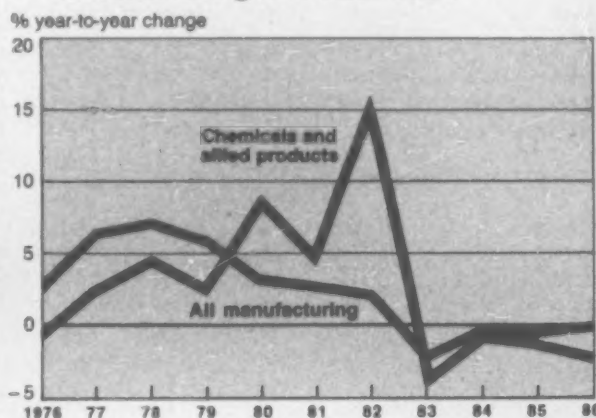
* For production and nonsupervisory workers in domestic employment. Source: Department of Labor

3 Employment in the U.S. Chemical Industry

Good gains for chemical productivity ...



... result in falling unit labor costs



Note: Productivity is output per workhour, calculated by dividing indexes for production by indexes for workhours of production employees. Unit labor costs are labor costs per unit of output, calculated by dividing indexes for wages by indexes for output per workhour. Sources: Department of Labor, Federal Reserve Board, C&EN calculations

In an era of much talk about improving productivity and competitiveness, U.S. chemical companies seem to be doing well. They have cut the number of manhours needed to produce a unit of product and also are holding in check the labor costs associated with production.

Productivity in the U.S. chemical industry in 1986 rose for the fourth year as production increased and workhours dropped. The increase was almost twice that for manufacturing as a whole. Much of the change in 1986 stemmed from in-

creasing production. Output of U.S. chemical plants increased nearly 5% over the previous year. But a drop of about 1% in workhours also helped, so that productivity in the chemical industry increased more than 5% over 1985.

By contrast, productivity for all manufacturing industries rose just 2.5% as production increased 2% and workhours declined only slightly.

Chemical companies also were able to keep wages pretty well in line, so that unit labor costs also were lower for the fourth straight

year. Labor Department figures show average hourly wages in the chemicals and allied products industry in 1986 rose just 3.3% over the previous year. However, the hourly wage for all manufacturing was just 2.2% above the previous year.

As a result of its greater rise in productivity, the chemical industry likewise outperformed all manufacturing in lowering unit labor costs, which fell 2% for chemicals in 1986 but were essentially unchanged for all manufacturing.

PRODUCTIVITY: A continued drop for workhours in the chemical industry brings improvement

Indexes, 1977 = 100	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976
CHEMICALS AND ALLIED PRODUCTS											
Production	132.9	127.1	121.6	113.9	103.8	112.6	106.4	113.3	106.3	100.0	92.0
Workhours	93.5	94.3	95.0	93.9	95.2	101.7	101.0	103.1	102.2	100.0	97.3
Productivity	142.1	134.8	126.0	121.3	109.0	110.7	105.4	109.9	104.0	100.0	94.6
Hourly production wages	186.1	180.1	172.7	164.8	155.0	141.8	129.2	118.2	109.2	100.0	91.9
Unit labor costs	130.9	133.7	135.0	135.9	142.2	128.2	122.6	107.6	105.0	100.0	97.2
ALL MANUFACTURING											
Production	129.2	126.4	123.4	113.9	102.2	110.5	108.2	110.7	106.1	100.0	94.1
Workhours	93.0	93.3	94.8	88.2	87.0	97.9	98.9	106.2	104.5	100.0	96.1
Productivity	138.9	135.5	130.1	124.8	117.5	112.9	109.4	104.2	101.5	100.0	97.9
Hourly production wages	171.1	166.9	161.5	155.4	149.6	140.7	128.1	118.0	108.6	100.0	91.9
Unit labor costs	123.2	123.2	124.1	124.4	127.3	124.7	121.5	113.2	107.0	100.0	93.8

Sources: Department of Labor, Federal Reserve Board

Exchange rates blur chemical trade figures

The much weaker dollar of the past year or so has given the U.S. chemical industry new strength in the world marketplace. After tailing off 2% in 1985, U.S. chemical exports rose almost 5% to \$22.8 billion last year. Meanwhile, growth of U.S. chemical imports advanced only 3% to \$15 billion.

As a result, the U.S. chemical industry, one of the very few U.S. industries that enjoy a favorable balance of trade, increased its trade surplus from \$7.2 billion to \$7.8 billion. That may not sound like an astounding achievement. But it comes on the heels of five successive years of decline from a lofty surplus of \$12.1 billion in 1980, as chemical export growth all but disappeared and chemical imports soared.

World chemical trade statistics don't give the U.S. chemical industry its due. That's because the U.S. dollar has fallen so drastically against most of the world's major currencies over the past two years. For

instance, preliminary statistics, in dollars, indicate that total world chemical trade increased a whopping 20% last year to an estimated \$184 billion. Given the weak economies in virtually all of the world's industrialized nations, that large an increase is impossible.

Behind this statistical aberration lie the drastic changes in currency exchange rates. For instance, the European Economic Community, by far the largest chemical exporter in the world, boosted its chemical exports 22%, measured in dollars. However, measured in European Currency Units, chemical exports from the 12 community countries actually were 6% lower last year than they were in 1985.

On a volume basis, world chemical exports probably grew no more than 5 to 6% last year. And U.S. chemical exporters no doubt increased their share of world chemical markets rather than lost market share, as the dollar figures indicate.

U.S. TOTAL TRADE BALANCE: The deficit keeps increasing

\$ Billions	1986	1985	1984	1979
Total exports	\$217.3	\$213.1	\$217.9	\$114.8
Total imports	370.0	345.3	325.7	120.7
Trade balance	-152.7	-132.2	-107.8	5.9

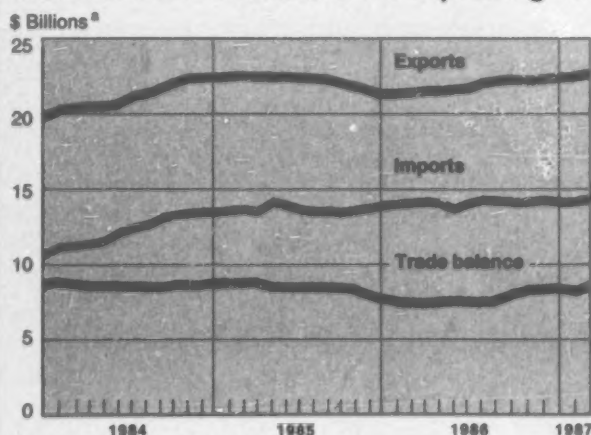
Source: Department of Commerce

U.S. CHEMICAL TRADE BALANCE: The surplus widens a little

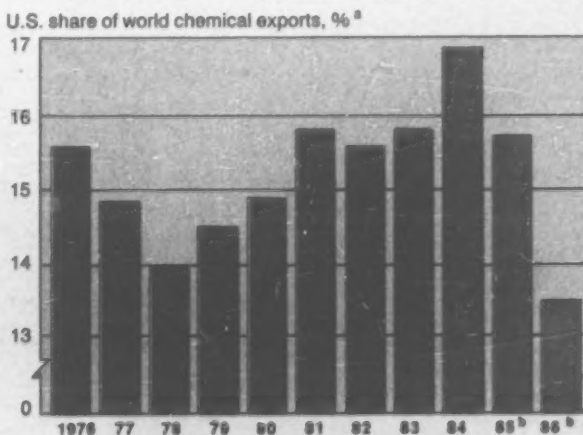
\$ Millions	1986	1985	1984	1979
Chemical exports	\$22,766	\$21,759	\$22,336	\$9,958
Chemical imports	15,001	14,533	13,697	4,772
Chemical trade balance	7,765	7,226	8,639	5,186

Source: Department of Commerce

U.S. chemical trade balance is expanding ...



... but U.S. share of world markets declines



WORLD TRADE: Weak dollar inflates data

\$ Millions	1986	1985	1984	1978
CHEMICAL EXPORTS				
World	\$184,000 ^a	\$153,000 ^a	\$146,421	\$68,760
U.S.	22,766	21,759	22,336	9,958
Canada	4,189	4,040	4,187	1,443
EEC, 12 countries	98,067	80,113	73,307	38,643
Belgium-Luxembourg	8,601	6,882	6,449	4,026
France	14,770	13,715	12,574	6,089
Italy	7,788	6,608	6,203	2,877
Netherlands	13,790	11,324	11,005	6,000
U.K.	14,390	12,174	11,014	5,468
West Germany	31,370	24,253	23,369	12,532
Switzerland	8,124	5,679	5,503	3,213
Japan	9,484	7,697	7,447	3,747
CHEMICAL IMPORTS				
U.S.	\$ 15,001	\$14,533	\$13,697	\$4,772
Canada	4,677	4,454	4,544	2,057
EEC, 12 countries	78,087	61,109	56,745	29,254
Belgium-Luxembourg	7,312	5,855	5,437	3,009
France	13,717	10,854	9,973	5,211
Italy	11,039	8,518	7,813	3,539
Netherlands	8,015	6,825	5,804	3,309
U.K.	10,949	7,425	8,470	3,588
West Germany	17,706	13,858	13,084	6,459
Switzerland	4,796	3,664	3,397	1,720
Japan	9,733	8,072	8,112	2,662

^a C&EN estimate. Sources: United Nations, Organization for Economic Cooperation & Development, European Economic Community, individual country data

U.S. TRADE: Higher with Europe and Asia

\$ Millions	1986	1985	1984	1978
U.S. CHEMICAL EXPORTS				
Canada	\$ 2,668	\$ 2,698	\$ 2,752	\$1433
Western Europe	7,032	6,742	6,497	3528
Eastern Europe	365	368	275	78
Communist Asia	441	513	645	11
Japan	3,081	2,908	2,861	852
Rest of Asia	3,377	3,024	3,292	852
Middle East	345	400	429	229
Latin America	4,025	3,681	3,827	2165
Australasia	689	704	842	362
Africa	447	456	510	275
Other	276	265	306	173
TOTAL	\$22,766	\$21,759	\$22,336	\$9958
U.S. CHEMICAL IMPORTS				
Canada	\$ 2,752	\$ 2,913	\$ 3,131	\$1287
Western Europe	7,357	7,118	6,392	2206
Eastern Europe	327	380	325	38
Communist Asia	179	163	157	18
Japan	1,792	1,412	1,312	398
Rest of Asia	623	457	377	64
Middle East	236	218	124	43
Latin America	942	1,216	1,208	183
Australasia	221	231	251	343
Africa	326	203	196	28
Other	244	222	224	164
TOTAL	\$15,001	\$14,533	\$13,697	\$4772

Source: Department of Commerce

U.S. TRADE, BY PRODUCTS: Gains by plastics, drugs, and organics help swell chemical exports

\$ Millions	Chemical exports				Chemical imports			
	1986	1985	1984	1978	1986	1985	1984	1978
Organic chemicals	\$ 6,293	\$ 6,012	\$ 6,093	\$3003	\$ 4,704	\$ 4,576	\$ 4,265	\$1205
Inorganic chemicals	1,771	1,967	2,184	1010	1,894	1,984	2,084	938
Radioactive materials	1,302	1,311	1,421	471	1,382	1,417	1,394	659
Dyeing, tanning, and coloring materials	174	139	158	121	487	352	358	121
Pigments, paints, and varnishes	333	322	335	188	348	266	232	38
Medicinals and pharmaceuticals	3,090	2,708	2,628	996	1,240	1,084	931	269
Flavors, perfumes, cosmetics, toiletries	468	478	498	250	679	577	521	150
Cleaning and polishing materials	302	292	308	204	214	172	118	44
Fertilizer, manufactured	1,935	2,160	1,815	612	865	967	1,142	683
Explosives and pyrotechnics	81	100	146	63	111	103	84	28
Plastics and resins	4,301	3,777	4,050	1672	1,837	1,631	1,484	309
Pesticides and disinfectants	664	614	707	a	580	399	308	a
Miscellaneous	2,032	1,878	1,992	1369	660	1,005	797	329
TOTAL	\$22,766	\$21,759	\$22,336	\$9958	\$15,001	\$14,533	\$13,697	\$4772

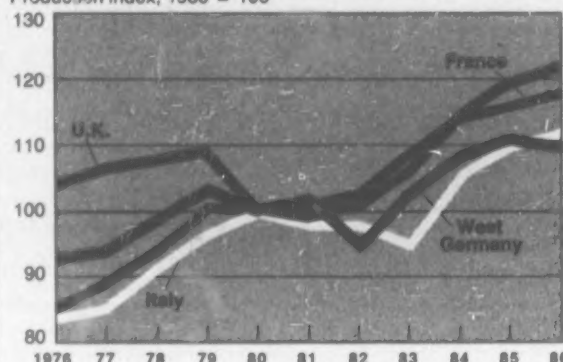
a Included in miscellaneous chemical products. Source: Department of Commerce

In 1986, for the fourth consecutive year, Bayer topped all other West European chemical companies in sales volume. And as was the case last year, the other two major West German chemical concerns, BASF and Hoechst, ranked second and third, with ICI of the U.K. coming in fourth. On the basis of profit margin, the U.K.'s Laporte, which earned 9.8% on sales, and Fisons (9.5%) remained at the top of the 14 companies surveyed by C&EN. But Italy's Montedison turned in the best improvement, doubling its margin to 3.6%.

The U.S. dollar fell more than 20% below average 1985 levels against the currencies of Belgium, France, Italy, the Netherlands, Switzerland, and West Germany. This fluctuation should be kept in mind when comparing company results for 1986, translated into dollars, with similar figures for previous years.

Growth slows for chemical output

Production index, 1980 = 100



CHEMICAL INDUSTRY TRENDS: Output changes little, prices ease, employment steady

\$ Billions (U.S.)	1986	1985	1984	1983	1982
WEST GERMANY					
Sales	\$ 64.5	\$ 50.5	\$ 49.5	\$ 49.7	\$ 48.5
Exports	33.2	26.1	25.1	24.0	22.9
Imports	18.8	15.0	14.0	13.6	13.0
Capital spending	3.5	2.4	2.2	2.7	2.8
Production index ^a	110.1	111.1	108.8	103.4	96.4
Price index ^a	114.6	121.6	118.1	113.9	113.7
Employees (thousands)	567	557	550	549	559
FRANCE^b					
Sales	\$ 40.7	\$ 31.8	\$ 30.9	\$ 30.1	\$ 30.4
Exports	15.7	12.8	12.2	11.5	11.2
Imports	12.5	10.0	9.2	8.9	9.1
Capital spending	1.9	1.3	1.1	1.0	1.1
Production index ^a	117.5	116.3	114.3	108.7	102.8
Price index ^a	156.0	160.0	153.1	139.9	128.2
Employees (thousands)	268	272	279	282	286
ITALY					
Sales	\$ 30.7	\$ 24.5	\$ 23.6	\$ 22.9	\$ 22.7
Exports	7.8	6.6	6.2	5.7	5.0
Imports	12.0	9.3	8.6	7.9	7.4
Capital spending	1.3	0.9	0.9	1.1	1.1
Production index ^a	111.8	110.3	106.2	100.0	98.3
Price index ^a	155.4	159.7	148.2	134.9	124.1
Employees (thousands)	230	233	241	251	260
U.K.^b					
Sales	\$ 30.6	\$ 26.3	\$ 25.2	\$ 25.6	\$ 28.2
Exports	14.3	12.1	11.0	10.5	11.5
Imports	11.0	9.0	8.8	8.1	8.2
Capital spending	1.9	1.6	1.4	1.4	1.9
Production index ^a	121.7	120.4	114.9	108.7	100.8
Price index ^a	133.4	131.6	125.1	119.1	113.5
Employees (thousands)	336	336	329	330	338
SPAIN^{b,c}					
Sales	\$ 20.7	\$ 16.1	\$ 15.2	\$ 14.2	\$ 15.2
Exports	3.1	2.9	2.7	2.2	2.2
Imports	4.7	3.1	3.0	2.8	2.9
Capital spending	0.4	0.3	0.2	0.3	0.4
Production index ^a	119.6	113.9	111.0	104.5	100.0
Price index ^a	177.7	175.9	163.6	147.4	131.0
Employees (thousands)	239	240	241	242	243

\$ Billions (U.S.)	1986	1985	1984	1983	1982
BELGIUM^{b,c,d}					
Sales	\$ 17.2	\$ 14.1	\$ 13.6	\$ 13.2	\$ 14.1
Exports ^d	12.2	9.6	9.1	8.8	8.9
Imports ^d	8.6	6.9	6.6	6.3	6.3
Capital spending	0.7	0.4	0.4	0.4	0.3
Production index ^a	120.2	117.1	113.3	107.3	103.1
Price index ^a	141.6	145.0	139.9	133.7	126.0
Employees (thousands)	91	90	89	88	88
NETHERLANDS					
Sales	\$ 16.0	\$ 13.9	\$ 13.6	\$ 13.1	\$ 12.5
Exports	15.7	12.9	12.5	12.0	11.3
Imports	9.5	8.0	7.2	6.8	6.7
Capital spending	1.2	0.8	0.8	0.7	0.6
Production index ^a	133.0	133.0	122.0	111.0	100.0
Price index ^a	105.0	123.0	116.0	115.0	114.0
Employees (thousands)	91	89	89	88	90
SWITZERLAND^b					
Sales	\$ 9.3	\$ 6.7	\$ 6.5	\$ 6.7	\$ 6.6
Exports	7.9	5.7	5.4	5.5	5.4
Imports	4.7	3.6	3.4	3.3	3.3
Production index ^a	125.5	122.9	115.7	109.6	103.0
Price index ^a	110.7	113.8	109.1	106.4	106.8
Employees (thousands)	68	66	65	68	na
SWEDEN					
Sales	\$ 5.0	\$ 4.1	\$ 4.1	\$ 3.9	\$ 4.0
Exports	2.5	1.9	1.8	1.8	1.6
Imports	3.2	2.7	2.5	2.7	2.6
Capital spending	0.4	0.3	0.3	0.3	0.3
Production index ^a	113.2	114.0	114.6	113.2	104.8
Price index ^a	158.0	155.5	147.0	135.5	120.4
Employees (thousands)	42	43	44	43	44
NORWAY					
Sales	\$ 2.3	\$ 2.0	\$ 2.1	\$ 2.1	\$ 2.0
Exports	1.3	1.2	1.2	1.1	1.0
Imports	1.4	1.1	1.0	0.9	0.9
Capital spending	0.2	0.1	0.1	0.1	0.1
Production index ^a	126.0	126.0	121.0	110.0	100.6
Price index ^a	129.0	127.0	126.1	123.6	117.9
Employees (thousands)	15	15	16	17	18

a 1980 = 100. b Excludes fibers. c Includes rubber and plastics processing. d Includes Luxembourg for exports and imports. na = not available. Sources: National agencies and European Council of Chemical Manufacturers' Federations (CEPIC)

MAN-MADE FIBERS: Little change in production last year

Millions of lb	1986		1985		1984		1983		1982		Change, 1985-86	
	Non-cellulosics ^a	Cellulosics	Non-cellulosics ^a	Cellulosics	Non-cellulosics ^a	Cellulosics	Non-cellulosics ^a	Cellulosics	Non-cellulosics ^a	Cellulosics	Non-cellulosics	Cellulosics
West Germany	1738	354	1764	372	1674	359	1654	334	1511	315	-1%	-5%
Italy	1430	66	1409	67	1329	68	1166 ^a	65	1091 ^a	102	1	-1
Spain	601	79	633	80	599	73	539	70	507	95	-5	-1
U.K.	524 ^c	207 ^d	557 ^c	247 ^d	561 ^c	372 ^d	541 ^c	330 ^d	506 ^c	263 ^d	-6	-16
France	392	44	427	44	456	61	437	83	435	100	-8	0
Benelux countries	378	108	365	95	318	94	189	90	198	124	4	14
Switzerland	216	0	226	0	218	0	204	0	183	0	-4	0
Ireland	161	0	140	0	136	0	118	0	114	0	15	0
Portugal	136	2	134	1	119	1	95	1	99	3	1	100
Austria	62	271	63	265	59	267	53	251	51	251	-2	2

a Includes polypropylene. b Excludes polypropylene. c Includes cellulose acetate filament. d Excludes cellulose acetate filament. Source: Comité International de la Rayonne et des Fibres Synthétiques

PRODUCTION: Declines last year just about balance increases

Millions of lb	1986	1985	1984	1983	Change 1985-86
FRANCE					
Sulfuric acid	8626	9433	9898	9024	-6%
Hydrochloric acid	1361	1446	1686	1483	-4
Chlorine	3151	3060	3103	2872	3
Sodium hydroxide	3304	3196	3274	3064	3
Ammonia	4455	4422	5170	4312	1
Benzene	1332	1399	1343	1373	-5
Toluene	83	89	87	90	-7
Xylenes	250	277	188	199	-10
Ethylene	4980	4749	4581	4563	5
Propylene	2283	2730	2652	2455	-16
Butadiene	641	634	667	620	1
Formaldehyde	176	203	210	208	-13
Polyethylene	2471	2266	2045	2070	9
Polypropylene	1034	933	871	842	11
Polystyrene	1089	1074	1060	1056	1
Polyvinyl chloride	1960	1804	1737	1796	9
Synthetic rubber	1193	1199	1218	1125	0
Phosphate fertilizers (P ₂ O ₅)	1267	1340	1495	1577	-5
ITALY					
Sulfuric acid	9170	9588	9370	9071	-4%
Nitric acid	2402	2599	2420	2261	-8
Phosphoric acid	830	886	996	999	-6
Chlorine	2106	2031	2095	1974	4
Sodium hydroxide	2294	2268	2359	2219	1
Sodium perborate	212	218	229	241	-7
Sodium silicate	213	176	211	194	21
Ammonia	4155	3250	3233	2494	28
Benzene	1107	1075	1179	1160	3
Toluene	854	766	688	658	11
Xylenes	893	952	871	804	-6
Formaldehyde	297	301	325	312	-1
Acetic acid	116	129	140	237	-10
Carbon black	418	403	380	339	4
Polyethylene	1504	1408	1602	1564	7
Polystyrene	785	707	695	725	11
Polyvinyl chloride	1408	1358	1493	1391	4
Nitrogen fertilizers (N)	6948	7217	7134	6003	-4

a Manufacturers' sales. b From petroleum refining only. Sources: Government agencies for each country

Millions of lb	1986	1985	1984	1983	Change 1985-86
U.K.					
Sulfuric acid	5125	5621	5829	5692	-9%
Hydrochloric acid ^a	346	337	345	286	4
Phosphoric acid	649	826	896	981	-21
Chlorine	2234	2269	2156	1980	-2
Benzene	1893	1863	1660	1597	2
Ethylene	3244	3162	2913	2540	2
Propylene	1885	2141	2147	1719	-12
Butadiene	420	655	570	523	-36
Acetone	271	323	355	268	-16
Formaldehyde	225	272	228	226	-17
Polyethylene	955	1144	893	896	-17
Polypropylene	651	592	568	506	10
Polyvinyl chloride	651	391	379	420	10
Synthetic rubber	636	593	636	571	7
WEST GERMANY					
Sulfuric acid	7344	7571	8002	8009	-3%
Hydrochloric acid	2048	2079	2104	1980	-1
Nitric acid	6210	6361	6284	5778	-2
Chlorine	7538	7686	7536	6900	-2
Sodium hydroxide	7485	7581	7408	6830	-1
Sodium carbonate	3173	3096	3000	2679	2
Sodium sulfate	359	306	281	275	17
Carbon black	844	852	841	797	-1
Ammonia	4146	5036	5183	4495	-18
Benzene ^b	2892	2723	2734	2939	6
Toluene	1052	860	816	691	22
Xylenes	1190	1089	1003	1127	9
Aniline	408	369	373	331	11
Ethylene	5868	6661	7093	6960	-21
Propylene	3093	3665	3969	3793	-16
Butadiene	1505	1851	1661	1580	-19
Ethylene oxide	1093	1073	1044	993	2
Ethylene glycol	500	504	509	450	-1
Propylene oxide	1174	1179	1083	1110	0
Propylene glycol	395	371	372	351	0
n-Butanol	689	604	589	562	14
Acetaldehyde	686	726	737	647	-6
Acetic acid	653	655	668	590	0
Ethanol	217	170	120	171	28
Formaldehyde	1265	1253	1283	1175	1
Methanol	1018	1302	1504	1470	-22
Phthalic anhydride	433	378	453	429	15
Polyethylene	2785	2725	2882	2996	2
Polyvinyl chloride	2732	2658	2490	2398	3
Synthetic rubber	1026	1007	988	951	2
Nitrogen fertilizers (N)	1684	1826	1843	1642	-8
Phosphate fertilizers (P ₂ O ₅)	311	394	473	552	-21

COMPANY RESULTS: Profit margins generally are a bit stronger while employment edges higher

	\$ Millions	Net sales	Net income	Profit margin	Capital spending	R&D spending	Employees (thousands)
Bayer (West Germany)							
1986	\$18,778.3	\$687.1	3.7%	\$1093.5	\$955.8	173.0	
1985	15,621.1	488.4	3.1	700.0	725.9	176.1	
1984	15,098.9	411.9	2.7	646.3	686.3	174.8	
1983	14,641.6	295.7	2.0	734.1	664.3	174.8	
BASF (West Germany)							
1986	\$18,650.2	\$419.4	2.2%	\$1224.4	\$676.5	131.5	
1985	15,094.2	339.5	2.2	950.3	488.1	130.2	
1984	14,175.4	314.0	2.2	719.6	435.8	115.8	
1983	13,769.0	202.7	1.5	639.2	466.3	114.1	
Hoechst (West Germany)							
1986	\$17,518.0	\$644.7	3.7%	\$1234.6	\$985.3	181.2	
1985	14,531.3	499.3	3.4	804.4	708.5	180.6	
1984	14,546.3	474.4	3.3	724.9	637.9	177.9	
1983	14,583.9	356.5	2.4	733.3	634.1	179.8	
Imperial Chemical Industries (U.K.)							
1986	\$14,862.2	\$879.8 ^a	5.9%	\$942.8	\$573.3	121.8	
1985	13,692.5	715.0 ^b	5.1	821.2	452.1	118.6	
1984	13,247.3	808.8 ^c	6.1	589.6	399.7	115.6	
1983	12,528.1	602.4 ^d	4.8	547.8	418.8	117.9	
Ciba-Geigy (Switzerland)							
1986	\$8,863.9	\$645.0	7.3%	\$684.4	\$903.9	82.2	
1985	7,406.9	598.4	8.1	493.1	680.5	81.0	
1984	7,435.7	505.1	6.8	428.5	619.6	81.4	
1983	7,019.5	369.5	5.3	395.2	594.3	79.2	
Montedison (Italy)							
1986	\$8,607.6	\$311.2 ^e	3.6%	\$570.8	\$207.9	66.6	
1985	7,402.8	128.3 ^f	1.7	342.6	157.2	69.7	
1984	7,047.2	(14.8) ^g	—	279.5	142.3	71.2	
1983	7,017.6	(207.4) ^h	—	295.6	171.2	72.8	
Rhône-Poulenc (France)							
1986	\$7,603.8	\$289.8	3.8%	\$732.5	\$426.3	78.0	
1985	6,240.5	257.1	4.1	460.5	317.6	78.0	
1984	5,858.4	227.6	3.9	395.2	281.7	80.0	
1983	5,658.4	12.9	0.2	365.4	286.0	80.8	
Norsk Hydro (Norway)							
1986	\$7,341.0	(\$50.6) ⁱ	—	\$1562.7	\$81.2	43.1	
1985	5,512.8	257.1	4.7%	825.0	58.1	26.4	
1984	5,067.8	247.2	4.9	651.0	29.5	19.8	
1983	4,719.5	147.7	3.1	593.0	29.0	18.8	
DSM (Netherlands)							
1986	\$7,229.4	\$198.0 ^j	2.7%	\$534.7	\$91.8	27.3	
1985	7,128.6	142.8 ^k	2.0	294.3	57.2	26.1	
1984	7,018.8	179.6 ^l	2.6	285.7	54.5	27.2	
1983	6,929.8	80.2 ^m	1.2	230.9	61.4	27.9	

	\$ Millions	Net sales	Net income	Profit margin	Capital spending	R&D spending	Employees (thousands)
Akzo (Netherlands)							
1986	\$6,373.5	\$366.5 ^m	5.7%	\$451.4	\$304.5	68.4	
1985	5,424.7	275.1 ⁿ	5.1	303.6	218.4	65.0	
1984	5,146.4	252.0 ^p	4.9	244.2	198.8	66.1	
1983	5,292.8	189.2 ^p	3.6	219.3	217.5	66.3	
Solvay (Belgium)							
1986	\$4,842.5	\$222.3 ^q	4.6%	\$517.1	\$192.6	44.8	
1985	3,796.6	167.8 ^r	4.9	271.1	131.8	44.5	
1984	3,871.5	200.2 ^s	5.2	195.6	126.7	43.5	
1983	3,887.0	128.8 ^t	3.3	162.3	127.1	44.2	
Sandoz (Switzerland)							
1986	\$4,645.0	\$300.6	6.5%	\$306.1	\$414.4	42.6	
1985	3,436.2	215.0	6.3	189.9	294.7	40.2	
1984	3,163.4	174.9	5.5	129.4	289.8	38.0	
1983	3,117.1	152.4	4.9	128.6	281.9	38.1	
Hoffmann-La Roche (Switzerland)							
1986	\$4,345.7	\$231.1	5.3%	\$293.7	\$623.7	46.5	
1985	3,634.3	183.6	5.1	220.2	486.3	45.5	
1984	3,519.1	161.8	4.6	214.0	486.2	46.2	
1983	3,576.2	156.4	4.4	216.1	473.5	45.9	
BOC International (U.K.)							
1986	\$2,851.3	(\$16.3) ^u	—	\$347.4	\$55.7	37.1	
1985	2,462.3	142.0 ^v	5.8%	312.8	46.2	36.9	
1984	2,811.5	106.0 ^w	3.8	322.6	56.6	38.7	
1983	2,582.1	83.2 ^x	3.2	468.1	40.8	39.1	
Fisons (U.K.)							
1986	\$1,030.2	\$97.7 ^y	9.5%	\$ 10.4	na	10.2	
1985	837.7	73.3 ^z	8.8	7.4	22.7	9.0	
1984	738.8	50.6 ^{aa}	6.9	9.4	20.1	8.6	
1983	554.5	38.1 ^{bb}	6.9	4.7	21.2	7.5	
Albright & Wilson (U.K.)							
1986	\$955.6	\$33.1	3.5%	\$ 47.8	na	6.6	
1985	832.1	27.8 ^{cc}	3.3	55.7	na	6.8	
1984	761.2	29.3 ^{dd}	3.8	46.8	na	6.3	
1983	865.3	31.9 ^{ee}	3.7	37.2	na	6.3	
UCB (Belgium)							
1986	\$659.4	\$31.5 ^{ff}	4.8%	\$ 40.2	\$28.7	6.5	
1985	524.3	17.0 ^{gg}	3.2	22.9	19.5	6.4	
1984	534.8	23.0 ^{hh}	4.3	21.6	18.4	6.5	
1983	572.4	22.0 ⁱⁱ	3.8	23.5	17.6	6.4	
Laporte Industries (U.K.)							
1986	\$618.2	\$80.4 ^{jj}	9.8%	\$ 33.0	na	4.1	
1985	481.0	46.2 ^{kk}	9.6	35.0	na	3.6	
1984	475.4	37.3	7.8	13.5	na	3.6	
1983	440.4	27.7 ^{ll}	6.3	7.7	na	3.5	

a Excludes nonrecurring loss of \$63.0 million. b Excludes nonrecurring loss of \$51.8 million. c Excludes nonrecurring loss of \$26.7 million. d Excludes nonrecurring loss of \$26.8 million. e Excludes nonrecurring minority interests' loss of \$96.8 million in 1986 and \$66.1 million in 1985. f Net loss. g Excludes nonrecurring gain of \$17.6 million and minority interests' loss of \$50.1 million. h Excludes nonrecurring minority interests' loss of \$4.6 million. i Excludes nonrecurring loss of \$22.4 million. j Excludes nonrecurring loss of \$13.0 million. k Excludes nonrecurring loss of \$17.6 million and minority interests' loss of \$17.5 million. l Excludes nonrecurring gain of \$6.3 million and minority interests' loss of \$29.1 million. m Excludes nonrecurring gain of \$9.5 million. n Excludes nonrecurring gain of \$0.8 million and minority interests' loss of \$22.0 million. o Excludes nonrecurring loss of \$10.6 million and minority interests' loss of \$6.7 million. p Excludes nonrecurring loss of \$36.0 million and minority interests' loss of \$3.0 million. q Excludes nonrecurring loss of \$83.3 million. r Excludes nonrecurring loss of \$50.5 million. s Excludes nonrecurring loss of \$60.9 million. t Excludes nonrecurring loss of \$25.7 million. u Excludes nonrecurring loss of \$5.6 million and pretax write-off of \$187.7 million. v Excludes nonrecurring loss of \$9.2 million. w Excludes nonrecurring gain of \$16.7 million. x Excludes nonrecurring loss of \$19.4 million. y Excludes nonrecurring loss of \$7.2 million. z Excludes nonrecurring loss of \$3.7 million. aa Excludes nonrecurring loss of \$5.6 million. bb Excludes nonrecurring loss of \$10.0 million. cc Excludes nonrecurring loss of \$3.5 million. dd Excludes nonrecurring loss of \$0.3 million. ee Excludes nonrecurring loss of \$1.5 million. ff Excludes nonrecurring loss of \$2.3 million. gg Excludes nonrecurring gain of \$6.2 million. hh Excludes nonrecurring gain of \$0.5 million. ii Excludes nonrecurring loss of \$3.0 million. jj Excludes nonrecurring gain of \$7.8 million. kk Excludes nonrecurring gain of \$4.1 million. ll Excludes nonrecurring loss of \$3.5 million. na = not available.

NOTE ON CURRENCY CONVERSION

For monetary statistics in this section, European currencies were converted to U.S. dollars by the following conversion rates:

	Belgium	France	Italy	Netherlands	Norway	Spain	Sweden	Switzerland	U.K.	West Germany
1986	44.67 francs	6.93 francs	1491 lire	2.45 guilders	7.39 crowns	140.05 pesetas	7.14 crowns	1.80 francs	0.682 pound	2.17 marks
1985	59.38 francs	8.99 francs	1909 lire	3.32 guilders	8.60 crowns	170.04 pesetas	8.60 crowns	2.46 francs	0.772 pound	2.94 marks
1984	57.78 francs	8.74 francs	1757 lire	3.21 guilders	8.16 crowns	160.76 pesetas	8.27 crowns	2.35 francs	0.748 pound	2.85 marks
1983	51.13 francs	7.62 francs	1519 lire	2.85 guilders	7.30 crowns	143.43 pesetas	7.67 crowns	2.10 francs	0.659 pound	2.55 marks
1982	45.69 francs	6.57 francs	1353 lire	2.67 guilders	6.45 crowns	109.86 pesetas	6.28 crowns	2.03 francs	0.571 pound	2.43 marks

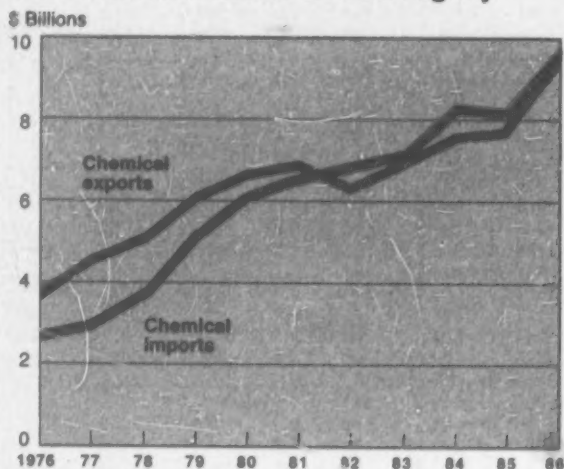
Source: International Monetary Fund

5 Foreign Chemical Industries-Japan

Last year, Japan experienced a rare downturn in its domestic economy, a slowdown that is reflected in the operating results of the country's major chemical companies. With very few exceptions, output of most volume chemicals was down. For those that did advance, the increase was modest. Only a few downstream products enabled the overall chemical production index to advance a meager 0.3% in 1986.

The chemical industry continued to trim its trade deficit, but this didn't help the industry's bottom line. In yen, sales of 10 top Japanese chemical companies dropped 14% last year. Profits slid 18%. But most of the damage was done in the first half. A better second half leads some Japanese chemical executives to believe that the worst may be over.

Chemical trade deficit shrinks slightly



Source: Ministry of International Trade & Industry

INDUSTRY TRENDS: Growth stalls

Production index, 1980 = 100	1986	1985	1984	1983	Change 1985-86
All manufacturing	121.7	122.1	116.7	104.9	0%
All chemicals	122.2	121.6	117.9	108.8	0
Inorganic chemicals and pigments	110.0	110.3	105.9	101.7	0
Alkalies and chlorine	94.4	95.9	95.2	90.7	-2
Organic chemicals	95.0	95.6	96.9	86.6	-1
Petrochemicals	114.8	114.1	113.7	98.5	1
Aromatics	111.9	112.0	106.6	96.1	0
Cyclic intermediates and dyes	115.3	117.0	116.9	105.1	1
Plastics	120.9	119.9	119.7	105.2	1
Synthetic fibers	96.6	100.6	100.2	97.1	-4
Synthetic rubber	105.1	105.8	106.1	91.6	-1
Fertilizer	71.5	76.8	79.8	77.4	-7
Textile materials	117.7	115.0	108.0	98.6	2
Medicinals and drugs	143.8	143.0	135.0	126.9	1

Source: Ministry of International Trade & Industry

PRODUCTION: Lower for many chemicals

Thousands of metric tons unless otherwise indicated	1986	1985	1984	1983	Change 1985-86
INORGANIC CHEMICALS					
Ammonia	1794	1981	2029	1881	-9%
Ammonium chloride	364	373	387	435	-2
Ammonium sulfate	1784	1837	1829	1722	-3
Calcium carbide	399	441	478	476	-9
Calcium superphosphate	514	529	559	559	-3
Carbon black	616	632	606	568	-3
Chlorine, liquid	881	926	897	818	-5
Hydrochloric acid	549	549	521	511	0
Nitrogen, millions of cu m	6293	6220	5896	5369	-2
Oxygen, millions of cu m	6786	7368	7216	6434	-8
Sodium carbonate	1022	1057	1036	1103	-3
Sodium hydroxide	3077	3075	3085	2863	0
Sodium silicate	603	594	596	588	2
Sulfuric acid	6561	6580	6458	6662	0
Titanium dioxide	223	217	205	196	3

ORGANIC CHEMICALS

Acetaldehyde	254	271	297	255	-6
Acetic acid	300	344	350	328	-13
Acetone	228	237	246	247	-4
Acrylonitrile	546	541	523	459	1
Benzene ^a	2071	2084	2013	1750	-1
Butadiene	656	639	627	556	3
Butanol	248	258	243	229	-4
Caprolactam	448	455	436	395	-2
Cyclohexane	515	524	492	454	-2
Diethyl phthalate	257	241	249	231	7
Ethylene	4289	4224	4390	3688	2
Ethylene dichloride	1908	1901	1939	1736	0
Ethylene glycol	339	440	429	357	-23
Ethylene oxide	489	554	533	468	-12
Methanol	221	254	280	373	-13
Octanol	235	230	246	219	2
Phenol	260	262	272	271	-1
Phthalic anhydride ^a	163	162	156	161	1
Propylene	3131	2980	2981	2658	5
Propylene glycol	223	219	205	194	2
Styrene	1417	1418	1423	1167	0
Terephthalic acid	1035	854	742	702	21
Toluene	805	803	784	831	0
Toluene diisocyanate	86	84	76	74	2
Urea	778	929	1120	980	3
Xylene	1570	1523	1401	1264	-16

PLASTICS

Phenolic resins	313	325	334	325	-4
Polyethylene	2066	2027	2251	2027	2
Polypropylene	1333	1304	1271	1304	2
Polystyrene	1598	1599	1503	1599	0
Polyvinyl chloride	1540	1550	1504	1550	-1

SYNTHETIC RUBBER

	1150	1158	1160	1002	-1
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^a Petroleum-based product only. Source: Ministry of International Trade & Industry

COMPANY RESULTS: Profitability little changed for chemical producers in past few years

\$ Millions	Sales	Net income	Profit margin	Total assets	Employees (thousands)
Asahi Chemical Industry^a					
1986	\$4373	\$83.9	1.9%	\$4361	15.9
1985	3910	73.3	1.9	3661	15.9
1984	3129	57.3	1.8	3027	15.9
1983	2985	47.0	1.6	3022	16.3

Mitsubishi Chemical Industries^b					
1986	\$3774	\$42.0	1.1%	\$5014	8.5
1985	3963	33.1	0.8	4016	8.2
1984	3271	7.0	0.2	3211	8.3
1983	3155	0.6	0.0	3479	8.5

Toray Industries^a					
1986	\$3235	\$53.9	1.7%	\$3947	11.7
1985	3177	78.2	2.5	3326	12.6
1984	2563	61.4	2.4	2663	13.2
1983	2588	66.0	2.6	2576	14.1

Sumitomo Chemical^c					
1986	\$3085	\$29.3	1.0%	\$3949	7.6
1985	3219	38.9	1.2	3277	7.1
1984	2876	58.4	2.0	2818	6.9
1983	2783	17.3	0.6	2775	7.9

Dainippon Ink & Chemicals^a					
1986	\$2396	\$33.0	1.4%	\$2214	6.3
1985	2102	26.4	1.3	1722	6.2
1984	1642	20.1	1.2	1449	6.0
1983	1681	19.0	1.1	1472	6.0

\$ Millions	Sales	Net income	Profit margin	Total assets	Employees (thousands)
Sekisui Chemical^a					
1986	\$2204	\$30.6	1.4%	\$1782	6.3
1985	1769	22.5	1.3	1439	6.2
1984	1415	16.9	1.2	1184	6.1
1983	1369	15.7	1.2	1199	6.1

Showa Denko^c					
1986	\$2116	\$22.1	1.0%	\$3163	4.8
1985	2066	20.1	1.0	2738	4.6
1984	1683	0.5	0.0	2069	4.6
1983	1500	(6.6) ^d	—	2086	5.0

Mitsui Toatsu Chemicals^a					
1986	\$2108	\$18.0	0.9%	\$2599	5.6
1985	2102	14.7	0.7	2242	5.4
1984	1672	8.6	0.5	1810	5.3
1983	1695	-14.7	d	1794	5.4

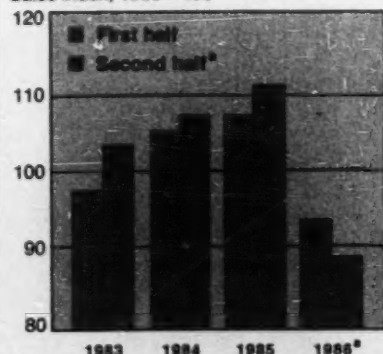
Teijin^a					
1986	\$2037	\$68.9	3.4%	\$2600	6.4
1985	2102	70.9	3.4	2210	7.0
1984	1766	57.3	3.2	1842	7.2
1983	1797	51.4	2.9	1846	7.1

Mitsubishi Petrochemical^c					
1986	\$1644	\$25.7	1.6%	\$2073	2.5
1985	2139	22.4	1.1	1939	2.4
1984	1592	43.3	2.7	1553	2.3
1983	1547	2.0	0.1	1644	2.5

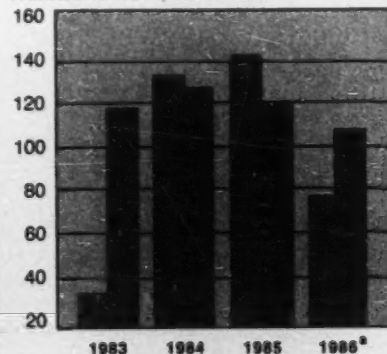
Note: Monetary statistics are converted from yen to U.S. dollars on the basis of \$1.00 equals: 1986, 166.9 Y; 1985, 204.6 Y; 1984, 244.6 Y; 1983, 236.7 Y. Year-to-year changes in sales, net income, and assets are affected by these fluctuations in the currency exchange rate. ^a Fiscal year ends March 31; 1986 data for these companies are based on actual results for the first half of the year and estimates for the second half. ^b Fiscal year ends Jan. 31. ^c Fiscal year ends Dec. 31. ^d Net loss. Source: Toyo Keizai Shinposha

Chemical sales have slumped, undercutting profits and squeezing margins

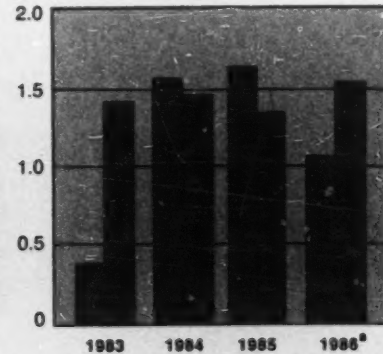
Sales index, 1980 = 100



Net income index, 1980 = 100



Net income as % of sales



Note: Based on results of 10 leading Japanese chemical companies: Asahi Chemical Industry, Dainippon Ink & Chemicals, Mitsubishi Chemical Industries, Mitsui Toatsu Chemicals, Sekisui Chemical, Showa Denko, Sumitomo Chemical, Teijin, and Toray Industries. The fiscal year for most, but not all, of these companies ends March 31. ^a Data for second half of 1986 are estimated. Source: Toyo Keizai Shinposha

Canadian chemical companies came across as leaner and meaner but more profitable operations last year, as the cost-cutting measures and divestitures that many implemented during the past few years finally bore results in 1986. Despite less than glowing production statistics and weaker prices for many of their basic organic and inorganic chemicals, some major Canadian chemical companies boosted their earnings significantly. This, despite only mediocre gains in sales.

Inorganic and aromatic chemicals suffered the worst setbacks in production. The biggest improvement came in plastics, especially low-density polyethylene. Fortunately, polyethylene is one of the few large-volume products in the industry that also enjoyed a sizable price increase last year.

Note on currency conversion: Monetary statistics in this section have been converted from Canadian dollars to U.S. dollars on the basis of \$1.00 U.S. equals: 1986, \$0.719 Canadian; 1985, \$0.734 Canadian; 1984, \$0.765 Canadian; 1983, \$0.804 Canadian; 1982, \$0.814 Canadian.

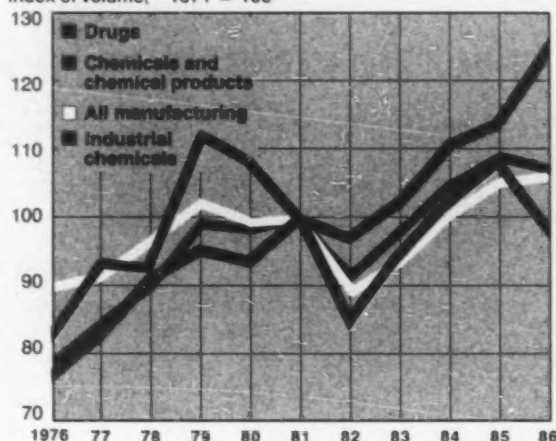
COMPANY RESULTS: Profits generally higher

\$ Millions (U.S.)	Sales	Net income ^a	Profit margin	Capital expenditures	Employees (thousands)
C-I-L Inc.					
1986	\$927.5	\$14.4	1.6%	\$38.1	5.6
1985	927.8	28.6	3.1	86.6	6.3
1984	899.6	29.1	3.2	90.5	6.3
1983	895.5	19.2	2.1	87.6	6.7
Celanese Canada					
1986	\$248.2	\$13.5	5.5%	\$ 9.0	2.1
1985	247.7	9.3	3.7	11.2	2.1
1984	263.2	4.7	1.8	9.4	2.8
1983	271.7	7.2	2.7	8.5	3.4
Du Pont Canada					
1986	\$893.7	\$43.4	4.9%	\$67.9	4.6
1985	870.7	15.1	1.7	52.4	4.9
1984	895.5	31.5	3.5	34.8	5.0
1983	897.6	28.3	3.2	20.3	5.0
Polysar					
1986	\$1473.6	\$20.0	1.4%	\$78.2	6.5
1985 ^b	1371.1	0.1	—	42.8	6.7
1984	1083.4	27.5	2.5	43.8	6.0
1983	1074.9	7.0	0.7	115.9	6.0
Union Carbide Canada					
1986	\$258.1	\$14.5	5.6%	\$29.7	3.3
1985	264.8	11.7	4.4	16.4	3.8
1984	300.3	9.0	3.0	15.0	4.1
1983	311.2	6.4	2.1	41.5	4.2

^a Excludes extraordinary gains and losses. ^b Acquired shares of Petrosar formerly held by Du Pont Canada and Union Carbide Canada.

Chemical output slips in Canada

Index of volume,^a 1971 = 100



^a Gross domestic product. Source: Statistics Canada

PRODUCTION: A poor year for inorganics

Thousands of metric tons	1986	1985	1984	1983	Change 1985-86
INORGANIC CHEMICALS					
Ammonia	3540	3620	3493	2888	-2%
Ammonium nitrate	948	1075	1035	934	-12
Ammonium phosphate	1149	1301	1383	1259	-12
Carbon black	154	173	177	na	-11
Chlorine	1536	1424	1424	1385	8
Hydrochloric acid	153	158	161	170	-3
Nitric acid	1024	1128	1100	1061	-9
Phosphoric acid, 100% P ₂ O ₅	547	629	691	656	-13
Sodium chlorate	373	336	313	294	11
Sodium hydroxide	1696	1589	1574	1528	7
Sulfuric acid	3536	3890	4043	3686	-9
ORGANIC CHEMICALS					
Acetone	na	23	25	25	—
Benzene	635	691	549	580	-8
Butadiene	146	132	127	133	11
Butylene	142	133	129	138	7
Ethylene	1909	1745	1484	1196	9
Formaldehyde	117	na	97	90	—
Methanol	na	na	1872	1671	—
Propylene	628	647	656	715	-3
Toluene	393	472	395	411	-17
Urea	2330	2033	2162	1445	15
Xylenes	356	415	406	426	-14
PLASTICS					
Polyesters, unsaturated	37	36	34	26	3
Polyethylene, high density	242	229	227	211	6
Polyethylene, low density	887	733	529	412	21
Polystyrene ^a	186	178	171	na	4
Polyvinyl chloride	na	na	252	243	—

^a Includes acrylonitrile-butadiene-styrene resins. na = not available. Source: Statistics Canada

SHIPMENTS: Industrial chemicals hit a snag in the mid-1980s

\$ Millions (U.S.)	1986	1985	1984	1983	1982	1981
All manufacturing	\$179,420	\$179,177	\$174,373	\$163,192	\$152,551	\$160,747
Chemicals and chemical products	13,066	12,898	12,821	12,613	11,573	11,118
Industrial chemicals, inorganic	2,565	2,639	2,683	2,556	2,343	1,848
Industrial chemicals, organic	2,725	2,833	2,966	3,102	2,947	2,699
Plastics and synthetic resins	1,396	1,317	1,331	1,302	1,126	1,275
Pharmaceuticals and medicinals	1,664	1,536	1,468	1,336	1,187	1,119
Adhesives	111	98	94	92	64	na
Paint and varnish	951	881	815	784	667	742
Soaps and cleansers	1,038	1,028	962	940	902	860
Toilet preparations	640	626	614	597	542	497
Agricultural chemicals	278	291	272	287	158	na
Printing ink	209	184	183	172	149	179
Miscellaneous	1,325	1,292	1,258	1,274	1,317	1,526
Synthetic fibers	586	563	568	607	485	na

na = not available. Source: Statistics Canada

CHEMICAL IMPORTS: Moderately higher

\$ Millions (U.S.)	1986	1985	1984	1983
Inorganic chemicals	\$ 378	\$ 374	\$ 381	\$ 330
Organic chemicals	1162	1107	1120	1019
Fertilizers and fertilizer materials	143	152	158	148
Synthetic and reclaimed rubber	169	160	158	129
Plastic materials	702	651	644	604
Plastic film and sheet	306	278	253	215
Other plastic shapes and forms	233	214	202	146
Dyes, except dyeing intermediates	58	49	56	62
Pigments, lakes, and toners	94	78	77	65
Paints and related products	133	127	113	89
Other chemical products	820	807	824	724
TOTAL	\$4198	\$3997	\$3988	\$3531
Imports from U.S.	\$3145	\$3034	\$3114	\$2754
U.S. share, %	75%	76%	78%	78%

Source: Statistics Canada

CHEMICAL EXPORTS: Not much change

\$ Millions (U.S.)	1986	1985	1984	1983
Chemical elements	\$ 172	\$ 158	\$ 174	\$ 150
Other inorganic chemicals	881	828	797	631
Organic chemicals	819	995	992	966
Fertilizers and fertilizer materials	815	946	1171	933
Synthetic rubber and plastic materials	629	587	481	419
Plastics, basic shapes and forms	327	238	203	159
Other chemical products	290	236	236	229
TOTAL	\$3933	\$3988	\$4054	\$3487
Exports to U.S.	\$2625	\$2669	\$2663	\$2286
U.S. share, %	67%	67%	66%	66%

Source: Statistics Canada

TRADE BALANCE: Surplus narrows markedly

\$ Billions (U.S.)	1986	1985	1984	1983	1982
Total exports	\$83.8	\$85.3	\$83.8	\$71.1	\$66.6
Total imports	81.3	77.1	73.2	60.8	55.3
Trade balance	2.5	8.2	10.6	10.3	11.3

Chemical trade falls into unwelcome deficit

\$ Millions (U.S.)	1986	1985	1984	1983	1982
Chemical exports	\$3933	\$3988	\$4054	\$3487	\$3284
Chemical imports	4198	3997	3988	3531	2919
Chemical trade balance	-265	-9	68	-44	365

Source: Statistics Canada

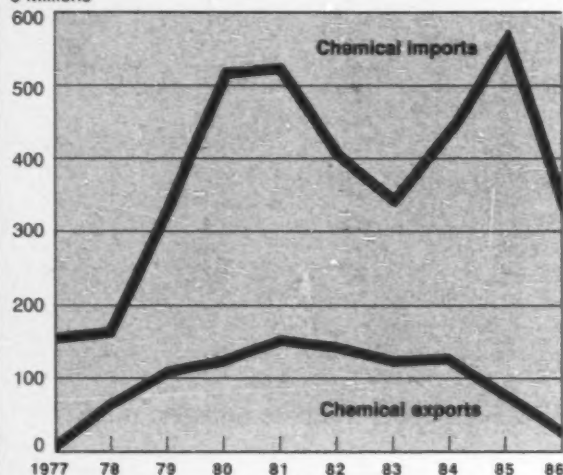
PRICES: Specialties rise, basics drop

Price index, 1981 = 100	1986	1985	1984	Change 1984-85
All commodities	119.6	118.6	115.4	1%
Chemicals and chemical products	116.1	114.5	113.1	1
Inorganic industrial chemicals	113.5	114.5	112.5	-1
Sulfuric acid	125.2	121.7	119.3	3
Chlorine	128.5	130.1	124.6	-1
Organic industrial chemicals	90.2	94.5	100.3	-5
Benzene-toluene-xylene	68.9	94.0	89.6	-27
Olefins	77.1	83.5	95.4	-8
Synthetic resins	110.4	109.4	111.4	-1
Polyethylene ^a	96.5	90.8	99.0	6
Polystyrene	93.9	93.6	101.5	0
Thermosets	108.3	115.1	113.2	-6
Synthetic fibers	100.1	101.2	101.5	-1
Pharmaceuticals	150.0	141.5	131.5	6
Paint and varnish	129.0	121.6	116.3	6
Soaps and cleansers	123.4	119.1	115.2	4
Toilet preparations	145.8	140.9	135.3	3
Agricultural chemicals	111.4	111.9	107.6	0
Pigments, lakes, and toners	119.6	115.0	112.2	4
Fertilizers, mixed	97.2	100.4	102.0	-3
Inks	111.4	110.4	108.8	1

^a includes both high and low density. Source: Statistics Canada

Imports slump but trade deficit stays wide

\$ Millions



Note: Trade in primary petrochemicals only; does not include secondary chemicals.
Source: Petróleos Mexicanos

DOMESTIC SALES: Many chemicals slump

Thousands of metric tons*	1986	1985	1984	1983	Change 1985-86
Acetaldehyde	150	199	212	200	-25%
Acrylonitrile	91	96	84	86	-5
Ammonia, anhydrous	1857	1804	1670	1455	3
Benzene	13	17	12	11	-24
Butadiene	68	110	106	84	-38
Cyclohexane	55	62	50	51	-11
Dodecylbenzene	102	100	101	107	2
Ethylene oxide	109	118	112	105	-8
Hexane	37	48	50	47	-23
Isopropyl alcohol	42	61	58	54	-31
Methanol	176	176	162	140	0
Polyethylene, high density	119	134	136	120	-11
Polyethylene, low density	282	266	222	251	6
Styrene	123	140	125	116	-12
Sulfur	462	457	455	319	1
Toluene	90	97	85	81	-7
Vinyl chloride	261	275	259	206	-5
o-Xylene	43	38	32	33	13
p-Xylene	226	268	263	131	-16

a Domestic sales by Petróleos Mexicanos (Pemex) of primary petrochemicals. Source: Pemex

CHEMICAL IMPORTS: Mexico cuts way back

Thousands of metric tons*	1986	1985	1984	1983	Change 1985-86
Acetaldehyde	26	70	70	42	-63%
Acrylonitrile	36	50	34	28	-28
Ammonia	13	39	0	0	-67
Butadiene	44	97	67	45	-55
Cyclohexane	19	33	26	3	-42
Dichloroethane	0	0	57	25	—
Dodecylbenzene	5	39	49	55	-87
Ethylbenzene	0	6	16	6	—
Ethylene oxide	2	48	11	0	-96
Isopropyl alcohol	26	50	44	25	-48
Perchloroethylene	15	14	15	9	7
Polyethylene, high density	82	42	19	49	95
Polyethylene, low density	76	127	63	88	-40
Propylene	26	26	26	17	—
Propylene tetramer	47	19	12	6	147
Styrene	49	112	93	66	-56
Toluene	47	43	37	0	9
Vinyl chloride	100	162	109	75	-38
o-Xylene	7	9	0	7	-22
p-Xylene	114	179	119	25	-36
TOTAL	748	1188	869	582	-37%

a Imports by Petróleos Mexicanos (Pemex) of primary petrochemicals. Source: Pemex

PRODUCTION: Huge gains for a few products

Thousands of metric tons*	1986	1985	1984	1983	Change 1985-86
Acetaldehyde	136	145	147	153	-6%
Acrylonitrile	54	49	49	55	10
Ammonia, anhydrous	1949	2261	2156	2355	-14
Benzene	222	178	156	139	25
Butadiene	18	18	20	18	0
Cyclohexane	39	32	30	49	22
Cumene	42	39	33	37	8
Dichloroethane	271	193	220	265	40
Dodecylbenzene	103	61	51	57	69
Ethane	2550	1905	1574	1638	34
Ethylbenzene	91	46	31	24	100
Ethylene	767	670	643	645	14
Ethylene oxide	114	71	97	112	61
Hexane	101	98	95	64	3
Hydrochloric acid	83	63	77	79	32
Isopropyl alcohol	11	14	14	12	-21
Methanol	182	192	197	206	-5
Nitrogen	49	46	47	45	7
Oxygen	206	211	200	214	-2
Polyethylene, high density	69	67	76	82	3
Polyethylene, low density	242	160	134	88	51
Propylene	232	207	208	191	12
Propylene tetramer	51	31	35	30	65
Styrene	69	33	30	24	109
Sulfur, recovered	456	475	461	377	-4
Toluene	238	220	216	223	8
Vinyl chloride	141	108	132	134	31
m- and p-Xylene	231	247	225	197	-6
o-Xylene	42	44	43	39	-5

a Production of Petróleos Mexicanos (Pemex) of primary petrochemicals. Source: Pemex

In 1986, overall industrial output in East Europe and the Soviet Union rose nearly 5%, racking up the largest increase since 1978. Growth varied from not quite 2% in Hungary to 5% in the U.S.S.R.

Most nations of the region also stepped up chemical production. Several recorded higher growth for chemicals than for industry as a whole. Romania led, claiming growth of 7.7% for all industry and 8.3% for chemicals. However, western experts discount its data as unrealistically high. Soviet chemical production rose 7%, twice the growth registered in 1985.

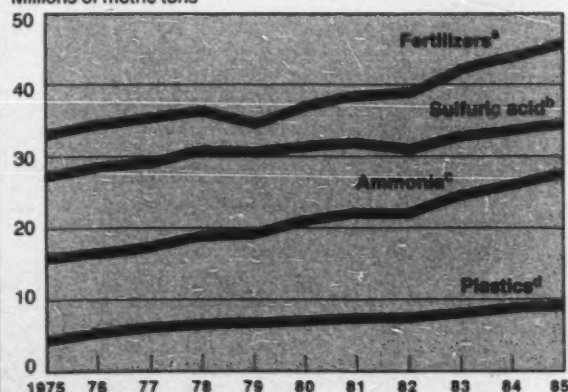
MAN-MADE FIBERS: Production edges higher in Soviet-bloc countries

Production, thousands of metric tons	1985	1984	1983	1982	Change 1984-85
NONCELLULOSIC FIBERS^a					
Bulgaria	70	64	60	52	9%
Czechoslovakia	110	101	90	89	9
East Germany	161	154	151	144	4
Hungary	26	22	21	20	19
Poland	171	166	161	135	3
Romania	186	170	158	153	9
U.S.S.R.	692	664	622	588	4
TOTAL	1414	1341	1262	1180	5%
CELLULOSIC FIBERS					
Bulgaria	42	41	39	38	1%
Czechoslovakia	60	59	58	55	2
East Germany	176	170	165	162	4
Hungary	7	7	6	8	0
Poland	80	76	69	64	7
Romania	62	60	60	58	4
U.S.S.R.	662	652	645	635	2
TOTAL	1090	1064	1042	1020	2%

^a Excludes olefins and textile glass. Source: Textile Economics Bureau

Production of important chemical products continues to expand in Eastern Europe

Millions of metric tons



Note: Data for U.S.S.R., Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, and Romania. ^a As N, P₂O₅, and K₂O. ^b 100% H₂SO₄. ^c Nitrogen content. ^d Including rayon for man-made fibers in U.S.S.R. Sources: Central Intelligence Agency, official national statistics from state central statistical bureaus

PRODUCTION GROWTH: Pace quickens

% annual change in gross output	1986	1985	1984	1983	1982
U.S.S.R. and East Europe					
All industry	4.8%	3.9%	4.3%	4.3%	2.4%
Bulgaria					
All industry	4.3	3.2	4.2	4.3	4.6
Chemicals	5.1	3.6	8.2	5.9	6.6
Czechoslovakia					
All industry	3.1	3.5	4.0	2.8	1.1
Chemicals	4.3	5.1	4.5	3.3	1.1
East Germany					
All industry ^a	4.3	4.4	4.2	4.1	3.1
Chemicals	4.8	3.7	4.3	2.9	4.8
Hungary					
All industry	1.8	0.7	3.2	1.2	2.5
Chemicals ^b	1.3	1.0	4.0	1.6	1.5
Poland					
All industry	4.4	4.5	5.2	6.4	-2.1
Chemicals	4.4	3.0	5.0	8.2	0.1
Romania					
All industry	7.7	4.9	6.7	4.7	1.1
Chemicals	8.3	0.3	8.1	5.4	1.5
U.S.S.R.					
All industry ^c	4.9	3.9	4.1	4.2	2.9
Chemicals ^c	7.0	3.4	5.2	5.9	3.0
All industry ^d	na	2.8 ^e	2.5	2.6	0.8
Chemicals ^d	na	5.2 ^e	3.5	6.9	2.1

^a Industrial commodity production. ^b For state and cooperative industry only. ^c Figures based on official Soviet statistics. ^d Figures based on Central Intelligence Agency estimates, giving lower results because of postulated upward bias in official figures. ^e Preliminary figure. na = not available. Sources: United Nations Economic Commission for Europe and state central statistical bureaus; Central Intelligence Agency

AGRICULTURAL CHEMICALS: Soviet Union increases availability of fertilizers

Thousands of metric tons	1986	1985	1984	1983	1982
Bulgaria					
Fertilizer supply ^a	na	865	938	1,009	1,036
Pesticide supply ^b	na	na	35.6	33.9	40.4
Czechoslovakia					
Fertilizer supply ^a	na	1,734	1,749	1,776	1,741
East Germany					
Fertilizer supply ^a	na	1,639	1,565	1,451	1,408
Pesticide supply ^b	na	26.7	26.0	26.0	26.7
Hungary					
Fertilizer supply ^a	na	1,338	1,524	1,586	1,528
Poland					
Fertilizer supply ^a	3,483	3,280	3,424	3,182	3,346
Pesticide supply ^b	14.4	12.4	11.1	14.7	16.3
Romania					
Fertilizer supply ^a	1,600 ^c	1,374	1,289	1,373	1,409
U.S.S.R.					
Fertilizer supply ^a	28,500 ^c	25,395	23,080	22,977	20,152
Nitrogen ^a	11,800 ^c	10,950	10,279	10,302	9,038
Phosphate ^{a,d}	8,991 ^c	7,615	6,625	6,465	6,115
Potassium ^a	7,700 ^c	6,822	6,167	6,201	4,991

^a Nutrient content basis, as N, P₂O₅, or K₂O. ^b On basis of active substance. ^c Estimated. ^d Includes ground phosphate rock. na = not available. Sources: Department of Agriculture, official national statistics from state central statistical bureaus

PRODUCTION: Moderate growth continues for several major chemical products

Thousands of metric tons, unless otherwise noted	1986*	1985	1984	1983	1982
U.S.S.R.					
Sulfuric acid, 100%	27,900	26,000	25,338	24,714	23,801
Mineral fertilizers ^b	34,700	33,194	30,808	29,733	26,738
Nitrogen ^b	14,770	14,223	13,328	13,014	11,593
Phosphate ^{b,c}	9,176	8,596	7,695	7,417	7,057
Potassium ^b	10,745	10,367	9,776	9,294	8,079
Synthetic ammonia ^d	na	19,100	17,677	16,904	14,605
Plastics ^e	5,300	5,010	4,819	4,419	4,058
Sodium hydroxide, 100%	3,200	3,056	2,972	2,853	2,783
Synthetic rubber ^f	na	2,005	1,955	1,812	1,795
Pesticides ^g	332	348	343	332	316
Rubber tires ^h	66,000	65,200	63,700	62,000	61,700
(thousands of units)					

BULGARIA					
Sulfuric acid, 100%	806	810	908	861	916
Mineral fertilizers ^b	673	640	690	687	698
Nitrogen ^b	541	469	479	483	459
Phosphate ^b	132	172	211	204	239
Synthetic ammonia ^d	na	1,138	1,138	1,124	1,033
Plastics	na	406	430	398	337
Sodium hydroxide, 100%	144	157	170	147	155
Synthetic rubber	na	26	26	25	25
Pesticides ^g	na	18	20	21	20

CZECHOSLOVAKIA					
Sulfuric acid, 100%	1,292	1,297	1,246	1,244	1,252
Mineral fertilizers ^b	na	1,204	1,190	1,175	1,166
Nitrogen ^b	na	582	576	591	568
Phosphate ^{b,c}	na	407	398	378	387
Potassium ^{b,d}	na	215	216	206	211
Synthetic ammonia ^d	na	818	827	809	725
Plastics	1,140	1,103	1,039	1,002	956
Sodium hydroxide, 100%	na	330	325	330	324
Synthetic rubber	na	70	71	67	66
Pesticides ^g	na	19	17	16	16

EAST GERMANY					
Sulfuric acid, 100%	na	882	885	926	920
Mineral fertilizers ^b	na	4,843	4,733	4,714	4,669
Nitrogen ^b	na	1,078	959	968	948
Phosphate ^{b,c}	na	299	308	315	286
Potassium ^b	na	3,465	3,465	3,431	3,434

Thousands of metric tons, unless otherwise noted	1986*	1985	1984	1983	1982
Synthetic ammonia^d	na	1210	1207	1210	1167
Plastics	na	1048	1057	1045	990
Sodium hydroxide, 100%	na	667	694	687	695
Synthetic rubber	na	140	152	155	155
Pesticides^g	na	60	58	54	53
Rubber tires^h	na	8364	7784	7380	7051
(thousands of units)					

HUNGARY					
Sulfuric acid, 100%	543	520	549	606	571
Mineral fertilizers ^b	1040	1066	1100	1110	1071
Nitrogen ^b	na	685	675	685	660
Phosphate ^b	na	253	286	285	269
Potassium ^{b,i}	na	130	139	140	142
Synthetic ammonia ^d	na	790	813	812	791
Plastics	423	389	385	345	326
Sodium hydroxide, 100% ^j	202	194	194	192	178
Rubber tires ^h	na	825	794	735	735
(thousands of units)					

POLAND					
Sulfuric acid, 100%	2969	2863	2769	2786	2676
Mineral fertilizers ^b	2526	2270	2356	2324	2284
Nitrogen ^b	1445	1254	1369	1341	1298
Phosphate ^b	948	889	869	872	868
Potassium ^{b,i}	133	127	118	111	118
Synthetic ammonia ^d	na	1490	1499	1430	1384
Plastics	631	603	601	535	451
Sodium hydroxide, 100%	na	384	379	392	363
Ethylene	na	261	256	198	175
Synthetic rubber	116	126	119	120	100
Rubber tires ^h	8409	8541	8103	6695	5322
(thousands of units)					

ROMANIA					
Sulfuric acid, 100%	na	1835	1915	1941	1600
Mineral fertilizers ^b	na	3097	3073	2913	2692
Nitrogen ^b	na	2197	2212	2091	2008
Synthetic ammonia ^d	na	2876	2857	2723	2583
Plastics	na	628	655	633	591
Sodium hydroxide, 100%	na	814	805	745	760
Synthetic rubber	173	156	156	147	160
Pesticides ^g	na	53	53	48	45
Rubber tires ^h	na	7210	5882	5346	5445
(thousands of units)					

a Approximate figures or estimates. b Nutrient content basis, as N, P₂O₅, or K₂O. c Including production of ground phosphate rock for direct applications and phosphate animal feeds. d Nitrogen content. e Including resins for man-made fibers. f Estimated. g On basis of active substance. h For all motor vehicle tires, excluding aircraft and bicycle tires. i Imported potash added to domestically produced nitrogen and phosphate to form multinutrient fertilizer. j Including regenerated NaOH. na = not available. Sources: Central Intelligence Agency, Department of Agriculture, Wharton Econometric Forecasting Associates, official national statistics from state central statistical bureaus

SOVIET FOREIGN TRADE: Rebound in exports brings a wider overall surplus

\$ Millions	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976
Exports ^a	\$97,096 ^b	\$86,956	\$91,492	\$91,652	\$87,168	\$79,377	\$76,437	\$64,912	\$52,435	\$45,227	\$37,269
Imports ^a	88,921 ^b	82,922	80,355	80,440	77,846	73,158	68,473	57,958	50,798	40,926	38,212
Trade balance	8,175 ^b	4,034	11,137	11,212	9,322	6,219	7,964	6,954	1,637	4,301	-943
Chemical exports ^a	na	na	2,804	2,422	2,309	2,380	2,139	1,606	1,284	1,063	939
Chemical imports ^a	na	na	4,223	4,070	3,886	4,031	3,732	2,803	2,188	1,850	1,668
Chemical trade balance	na	na	-1,419	-1,648	-1,577	-1,651	-1,593	-1,197	-904	-787	-729

a Free on board. b Approximate values. na = not available. Sources: Central Intelligence Agency, Wharton Econometric Forecasting Associates, based on official Soviet statistics and exchange rates

SOUTH KOREA

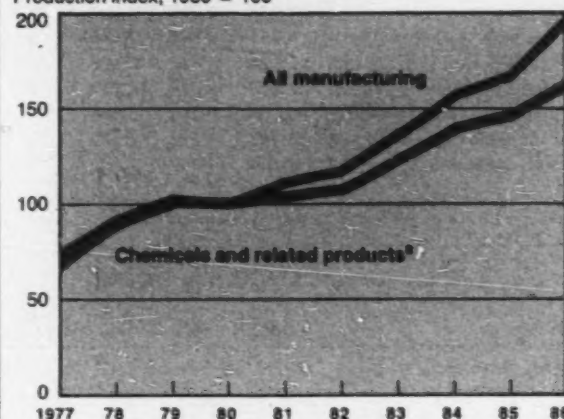
INDUSTRY TRENDS: Strong growth in 1986

Index, 1980 = 100	1986	1985	1984	1983	Change 1985-86
Chemicals, petroleum, coal, rubber, and plastic products					
Production	164.7	146.6	140.7	123.7	12%
Shipments	152.5	138.1	132.6	119.5	10
Inventories	139.3	132.4	125.2	119.5	5
Industrial chemicals					
Production	142.6	129.4	126.4	116.0	10
Shipments	156.2	141.5	134.4	124.5	10
Inventories	128.6	137.0	117.3	114.2	-6
Other chemical products					
Production	189.7	171.7	160.8	141.7	10
Shipments	186.8	168.6	158.7	139.2	11
Inventories	192.0	183.8	159.3	141.6	5
Rubber products					
Production	184.2	158.1	158.4	120.3	17
Shipments	184.1	158.4	158.2	120.1	16
Inventories	141.9	139.4	138.2	99.8	2
Plastic products					
Production	173.2	153.6	145.3	124.2	13
Shipments	173.7	154.7	146.1	123.6	12
Inventories	159.5	130.6	139.9	132.0	22
All manufacturing					
Production	199.4	167.1	160.6	139.0	19
Shipments	188.9	160.5	153.6	135.8	18
Inventories	147.7	150.3	138.0	126.0	-2

Source: Bureau of Statistics of the Korean Economic Planning Board

Industrial growth in South Korea regains a faster pace

Production index, 1980 = 100



a Includes petroleum, coal, rubber, and plastics products.
Source: Bureau of Statistics of the Korean Economic Planning Board

PRODUCTION: Plastics make good gains

Thousands of metric tons	1986	1985	1984	1983	Change 1985-86
Sulfuric acid	1898	2028	1975	1610	-6%
Complex fertilizers	1863	1944	1861	1614	-4
Urea fertilizers	812	839	858	737	-3
Ammonia	519	538	565	523	-3
Ethylene	534	562	526	491	-5
Polyvinyl chloride	473	411	344	323	15
Polyethylene	385	353	317	279	9
Polyester fibers	320	291	265	217	10
Sodium carbonate	264	251	248	231	5
Sodium hydroxide	251	229	215	202	10
Benzene	301	216	171	159	40
Polystyrene	248	134	132	123	85
Polypropylene	263	259	219	195	2

Source: Bureau of Statistics of the Korean Economic Planning Board

FOREIGN TRADE: Chemical imports surge

\$ Millions	1986	1985	1984	1983
Exports ^a	\$34,714	\$30,283	\$29,245	\$24,445
Imports ^b	31,584	31,136	30,631	26,192
Trade balance	3,130	-853	-1,386	-1,747
Chemical exports	1,068	936	845	677
Chemical imports	3,495	2,789	2,709	2,242
Chemical trade balance	-2,427	-1,853	-1,864	-1,565

a Free on board. b Includes cost, insurance, freight. Source: Korean Office of Customs Administration

AUSTRALIA

PRODUCTION: Major chemicals slump

Thousands of metric tons	1986 ^a	1985 ^a	1984 ^a	1983	Change 1985-86
Chemicals					
Hydrochloric acid, 100%	54	58	57	60	-6%
Nitric acid, 100%	193	200	189	189	-4
Sulfuric acid, 100%	1788	1773	1726	1782	1
Ammonium sulfate	205	243	217	200	-16
Superphosphate ^b	2479	2586	2663	2986	-4
Plastics and resins	880	na	815	720	na
Synthetic detergents	239	226	228	220	6
Unsupported plastics film, sheeting	162	157	139	na	3
Polyethylene ^c	120	118	108	na	2
Polyvinyl chloride ^d	15	14	14	17	7

a Year ending June 30. b Includes double and triple superphosphates and ammonium phosphate expressed in terms of single phosphate (22% P₂O₅ equivalent). c Low and high density. d Including copolymers. na = not available. Source: Australian Bureau of Statistics

FOREIGN TRADE: Imports outpace exports

\$ Millions	1986 ^a	1985 ^a	1984 ^a	1983 ^a
Exports ^{b,c}	\$22,990	\$23,104	\$21,804	\$20,184
Imports ^d	24,305	22,591	21,374	19,960
Trade balance	-1,315	513	430	224
Chemical exports ^{b,c}	413	422	455	431
Medicinal products	103	95	108	102
Chemical imports ^d	2,119	1,982	1,959	1,671
Organic chemicals	537	523	554	441
Resins, plastic materials	476	441	441	343
Medicinal products	275	228	201	182
Chemical trade balance	-1,706	-1,560	-1,504	-1,240

a Year ending June 30. b Free on board. c Includes re-exports. d Values for customs purposes, free-on-board basis. Source: Australian Bureau of Statistics

CHINA

PRODUCTION: Up for major chemicals nearly across the board

Thousands of metric tons, unless otherwise noted	1986	1985	1984	1983	Change 1985-86
Fertilizer^a	14,258	13,222	14,602	13,789	8%
Nitrogen (N)	na	11,438	12,210	11,094	na
Phosphate (P ₂ O ₅) ^b	na	1,760	2,360	2,666	na
Potash (K ₂ O)	na	24	32	29	na
Synthetic ammonia	17,195	17,212	18,374	16,771	0
Sulfuric acid, 100%	7,510	6,764	8,172	8,696	11
Sodium hydroxide	2,458	2,347	2,222	2,123	5
Sodium carbonate	2,150	2,011	1,880	1,793	7

Thousands of metric tons, unless otherwise noted	1986	1985	1984	1983	Change 1985-86
Calcium carbide	na	1,953	1,846	1,808	na
Plastics	1,283	1,208	1,180	1,121	6%
Man-made fibers	1,016	945	735	541	8
Synthetic detergents	na	1,005	810	677	na
Ethylene	642	651	648	654	-1
Pesticides	223	211	299	331	6
Pharmaceuticals	107	na	54	48	na
Rubber tires ^c	19,932	18,527	15,690	12,710	8

a Nutrient content. b Including production of ground phosphate rock for direct application and phosphate animal feeds. c In thousands of units, not including wheelbarrow and bicycle tires. na = not available. Source: State Statistical Bureau of the People's Republic of China

CHEMICAL IMPORTS: Generally higher

\$ Millions ^a	1985	1984	1983	Change 1984-85
Organic chemicals	\$ 698	\$ 591	\$ 492	18%
Inorganic chemicals	321	278	266	16
Dyeing, tanning, coloring materials	141	78	69	81
Medicinal and pharmaceutical products	103	71	49	45
Essential oils, perfumes, cleansing materials	26	12	8	116
Fertilizers ^b	1481	1616	1395	-8
Explosives, pyrotechnic products	2	0.4	0.2	297
Plastic materials, resins, cellulose esters and ethers	1449	1116	612	30
Other chemical materials	254	329	287	-23
TOTAL	\$4476	\$4091	\$3177	9%

a Includes cost, insurance, and freight. b Manufactured. Source: General Administration of Customs of the People's Republic of China

CHEMICAL EXPORTS: Continued growth

\$ Millions ^a	1985	1984	1983	Change 1984-85
Organic chemicals	\$ 314	\$ 281	\$ 303	11%
Inorganic chemicals	291	275	262	6
Dyeing, tanning, coloring materials	78	72	79	9
Medicinal and pharmaceutical products	302	262	268	15
Essential oils, perfumes, cleansing materials	111	113	104	-1
Fertilizers ^b	2	0.3	2	501
Explosives, pyrotechnic products	114	161	68	-29
Plastic materials, resins, cellulose esters and ethers	42	42	45	1
Other chemical materials	123	102	117	21
TOTAL	\$1377	\$1309	\$1249	5%

a Free on board. b Manufactured. Source: General Administration of Customs of the People's Republic of China

TAIWAN

INDUSTRY TRENDS: Strong gains last year

Industrial production indexes, 1981 = 100	1986	1985	1984	1983	Change 1985-86
All manufacturing	155.0	133.5	132.0	117.0	16%
Chemical materials	179.0	149.0	139.6	115.4	20
Basic chemicals	143.7	125.7	118.6	107.1	14
Petrochemicals	170.6	154.7	144.8	114.3	10
Fertilizers	85.8	65.6	75.2	74.0	31
Synthetic fibers	185.2	146.7	136.6	117.8	26
Plastics and resins	212.3	164.6	153.1	123.8	29
Chemical products	178.2	153.7	141.8	125.2	16

Source: Taiwan Ministry of Economic Affairs

FOREIGN TRADE: Chemical deficit widens

\$ Millions	1986	1985	1984	1983
Exports ^a	\$39,789 ^b	\$30,723	\$30,456	\$25,123
Imports ^c	24,165 ^b	20,102	21,959	20,287
Trade balance	15,624 ^b	10,621	8,497	4,836
Chemical exports ^{a,d}	1,487	1,340	1,244	1,044
Chemical imports ^{b,d}	4,161	2,966	3,203	2,815
Chemical trade balance	-2,674	-1,626	-1,959	-1,771

a Free on board. b Estimated. c Includes cost, insurance, and freight. d Includes chemicals and chemical products, but does not include plastic and rubber products. Sources: Taiwan Council for Economic Planning & Development, C&EN estimates

PRODUCTION: Some chemicals up sharply

Thousands of metric tons, unless otherwise noted	1986	1985	1984	1983	Change 1985-86
Man-made fibers	1359	1112	970	840	22%
Sulfuric acid	815	733	762	678	11
Polyvinyl chloride	795	633	634	522	26
Ethylene	868	792	660	499	10
Vinyl chloride	668	511	492	458	31
Ammonium sulfate	604	507	434	381	19
Ammonia, anhydrous	323	252	327	378	28
Sodium hydroxide	366	387	351	295	-5
Xylene	237	270	291	219	-12
Compound fertilizer	302	249	301	275	21
Propylene	441	415	341	250	6
Hydrochloric acid	256	228	241	212	12
Benzene	285	285	249	144	0
Urea	214	139	179	171	54
Calcium superphosphate	248	132	177	159	88
Ethylene glycol	222	199	189	151	12
Oxygen ^a	506	347	198	125	46
Polyethylene ^b	398	350	270	190	14
Paints	184	130	123	108	41

a Millions of cubic meters. b High and low density. Sources: Taiwan Council for Economic Planning & Development, Petrochemical Industry Association of Taiwan, Petrochemical Industry Journal (Taiwan)

JUNE 22, 1987

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CHEMICAL & ENGINEERING

NEWS

Methane to Gasoline

New Zealand plant meets expectations Page 22

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Textile finishing chemicals
face solid growth Page 9
CALENDAR OF EVENTS
Scientific meetings Page 28

News of the Week

■ **Battle over the patenting of new, genetically engineered animal life forms heats up.** Page 4

■ **Margaret Thatcher's re-election as Britain's prime minister doesn't bode well for U.K. science, already hard-pressed for financial support.** Page 5

■ **Imperial Chemical Industries, with its acquisition of Belgium-based European Seeds Co., moves forward aggressively into worldwide seeds business.** Page 5

■ **"Loyalty contracts" between an individual chemical shipper and an individual ocean common carrier will not be challenged by the Justice Department.** Page 6

■ **Monsanto seeks EPA permission to field test a system that tracks distribution of genetically engineered microorganisms in soil.** Page 6

Business

Textile finishing chemicals, which are supplied by a large number of dynamic small- and medium-sized companies, represent a \$330 million, steady-growth market. Page 9

Government

Several bills being considered by Congress would provide specific funding for academic research facilities—a move that is generally viewed favorably by both legislators and researchers. Page 18

Science

Doped polyacetylene, with copperlike conductivity at room temperature and remarkable stability, is synthesized by BASF chemists. Page 20

Proposals to carry out contract projects relating to preparation of compounds for investigation or use against AIDS are sought by the National Cancer Institute. Page 21

Meetings

C&EN's semiannual calendar lists meetings and other events of interest to chemists and chemical engineers. Page 28

Cover: New Zealand Synthetic Fuels Corp.
methane-to-gasoline plant at Motunui

Letters	2
Concentrates	
Business	7
Government	17
Science/Technology	19
The Departments	
ACS News	26
Newsclips	48



Technology

World's first methane-to-gasoline plant, which has been operating for just over a year in New Zealand, has met its strategic goal of reducing New Zealand's dependence on foreign oil. Page 22

Textile Finishing Chemicals: Slow but Steady Growth Ahead

Market for these chemicals, supplied by number of feisty small- and medium-sized firms, amounts to \$330 million and is growing 5% annually

Marc S. Relsch, C&EN New York

The textile chemical industry has been buffeted by the same ill wind affecting its mill customers: Foreign suppliers of finished fabric, apparel, home furnishings, and industrial textiles have been taking an increasingly larger share of the U.S. market.

The import problem is only a part of mill and textile chemical producers' woes. The textiles business is already a complex one. Mills and chemical producers, particularly of finishing chemicals, have to balance, on the one hand, the demand for products to suit fashions of the moment in apparel and home furnishings, and, on the other hand, environmental worries such as form-

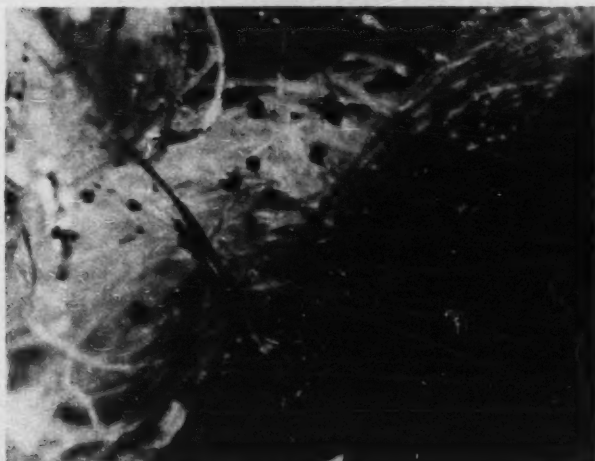
aldehyde in resin-cured, permanent-press finishes that is believed to pose a health threat to textile cutting room operators.

The U.S. textiles business, however, is not moribund. Although some huge textile mills, such as Milliken and Burlington Industries, operate along with large chemical suppliers, such as Du Pont and Dow Corning, the industry is basically characterized by a large number of feisty small- and medium-sized textile and chemical firms. Their specialty products or chemical formulations give them a small piece of the action in a sometimes frantic but always energetic textile industry. According to the July 1986 Textile Chemist & Colorist Buyer's Guide, 168 firms supply textile finishing chemicals.

The U.S. textiles market is huge—worth, according to industry estimates, more than \$50 billion in annual sales. The American Textile Manufacturers Institute (ATMI) estimates last year's U.S. market volume at 35.7 billion square-yard equivalents, based on U.S. govern-

ment figures. Of that number, 23 billion square-yard equivalents was produced in the U.S., and the remainder, or about 36%, was imported. In apparel alone, imports of finished apparel and finished fabrics took 52% of the U.S. market. Overall, according to ATMI, imported fabrics have grown at an annual average rate of 24% over the past five years.

The textile chemical industry has not fared quite so badly and has experienced modest growth. According to Steve R. Daigle, project manager for industry consultant Charles H. Kline & Co., the entire market for textile wet processing chemicals was worth some \$675 million in 1986. Surface finishing chemicals, the value-added components—which affect fabric performance and which consumers can feel, sometimes see, and base a buying decision on—were worth about half that amount, or \$330 million. Those surface finishing chemicals include a huge number of easy-care resins, water- and soil-repellent finishes, hand modifiers and softeners, flame re-



Microscopic view of carpet fiber samples shows fungus control properties of antimicrobials such as Dow Corning's Sylgard. Untreated sample (left) shows no resistance to fungus growth; sample on right was treated with antimicrobial

New generation of soil and stain protectors enters broadloom market

Consumers have been able to shop retail outlets for soil- and stain-resistant nylon carpet for a number of years now. Recent improvements in finishing technology, however, have led consumers to expect a new level of "easy-care" performance in residential carpet. Fiber producers, finish suppliers, and carpet retailers all hope to reap the benefits of this market expansion.

At the forefront promoting new finishing technology for the \$9 billion a-year residential carpet business are primary nylon fiber producers Du Pont, Allied-Signal, and Monsanto. In quick succession in fall 1986, Du Pont introduced Stainmaster-certified carpets, Allied-Signal followed with Anso V, and Monsanto introduced its gold and silver label wear-rated nylon broadloom.

All the fiber producers began with previous state-of-the-art fluorochemistry as a component specified in their certification programs to label the new generation carpeting produced by broadloom mills. But each chose a different approach to provide the ultimate consumer with carpeting from which tomato juice or a children's popular red soft drink could be washed out even after the initial spill had dried.

Du Pont's Stainmaster carpet has three basic components, says K. Bruce Koepcke, carpet fibers division market manager. The first is top grade nylon fiber, second, improved Teflon

fluorochemical treatment for durable dry soil resistance, and third, the new Stainmaster component, a proprietary polymer treatment of the dyed carpet fiber that "closes the leftover dye sites and makes them no longer available for staining," says Koepcke.

The Du Pont manager says only that the Stainmaster proprietary polymer is of a "class of materials used as dye resists in the past." The polymer is applied to the carpet after tufting and during the finishing process.

He believes that ultimately the market for the latest generation nylon carpets could capture 70% of the residential carpet business. In doing so, it certainly would expand the market for Du Pont's nylon carpet fibers and "increase dollar volume of the market," he says.

Allied-Signal's Anso V carpet system starts with the firm's fluorochemical-treated Anso IV nylon fiber. A stain-resistant polymer is added to the carpet by the mill and the resultant carpet must pass stringent certification standards.

Mills that use Monsanto's fiber and certification labels have two options. They may add a polymer treatment to the silver label carpet in the finishing stage for enhanced soil and stain resistance, or they may opt for the gold label treatment. According to R. J. Snooks, Monsanto's manager of nylon product development, the treatment for

nylon fiber destined for the gold label carpet is applied to the nylon fiber in the dry-spinning stage prior to the fiber-drawing process when the fiber is at 280 °C.

The stain-resistant agent is a low-molecular-weight sulfonated phenolic resin. When the fiber is drawn, the stain-resistant agent is locked into the fiber itself, Snooks says. Dyeing of carpet fiber can occur after treatment by applying heated dye to the fiber. The dye sites do not accept color at the temperature of most household liquids, thus allowing easy cleanup of potentially staining spills even after they have dried.

Like his competitors in the fibers business, Snooks sees an increase in both production and sales of high-value, higher-priced carpet. "I think there is potential here to see significant poundage of our fiber sold on the market," he says.

3M, which is not itself a nylon fiber producer but is a major branded textile fluorochemical treatment supplier, also is seeking a piece of the action of fifth-generation nylon carpeting. According to Tom G. Gerlach, marketing communications manager of the protective chemicals division, 3M is introducing Scotchgard stain release for carpeting. 3M has programs in place with large carpet mills such as Shaw and Coronet and plans to introduce branded programs on the retail market.

tardants, and a host of specialty antistatic compounds and biocides.

Textiles, says Daigle, are "not a dynamic growth category." But, he adds, the consulting firm believes textile chemicals have not done too badly because a lot of business that left the U.S. was for the less expensive commodity textiles. Textile specialty chemicals are more in use for more expensive fabrics. As a result, specialty textile chemical sales have been growing at a rate of about 5% a year, a little higher than growth of gross national product.

Industry consultant Ed Hochberg concurs on the growth trends for textile chemicals. He sees a trend in the industry to greater emphasis on industrial and home furnishings tex-

tiles, including broadloom, for which competition from the Far East is minimal. Chemical applications likely will follow that trend, he points out.

Textile finishing chemicals make a large contribution to the final textile product, according to Martin Tambor, textile technical manager for National Starch & Chemical. "Chemicals are cheaper than fibers," he says. "In many cases 10% or more of the weight of a textile comes from chemicals. Durable-press resins alone can account for 8% of a fabric's weight."

National Starch's textile chemicals group is a major producer of durable-press resins used on all cotton and blends of cotton with man-

made fibers such as polyester. In addition, National Starch produces and markets a line of polyolefin and organic nitrogen-containing cationic softeners as well as a line of silicone softeners. Tambor says that National Starch's polymer group, which formerly was Procter Chemical, formulates and synthesizes its own blend of proprietary products. Textile chemical businesses, he adds, "tend to do less than \$15 million in business annually mostly because they are small, highly responsive concerns in a competitive business where short response time to mill customer requirements is important."

Many of those textile companies are now working to bring to the

market low-formaldehyde or no-formaldehyde durable-press resins because of concern that possible exposure to formaldehyde fumes may pose a health risk to workers in cut-and-sew operations. Tambor says that National Starch has just introduced a no-formaldehyde, glyoxal-based, durable-press resin called Protorez. "It is priced at a premium compared with low-formaldehyde resins. The problem is that no one can come up with a cheap substitute for urea formaldehyde."

National Starch also is working on durable-press polymers that may allow completed garments to be dyed after the polymer has been applied. Consequently, the company hopes to take part in an industry trend that promises to provide garments in a given size and color in 10 days instead of the six to 10 weeks it now takes, Tambor says.

Sequa Chemicals, formerly Sun Chemical, also is a major supplier of permanent-press resins to the textile industry. Sequa is ready for an industry switch to low-formaldehyde or no-formaldehyde, permanent-press resins when the industry is ready for it. According to Sequa general manager Jack Cabrey, Sequa pioneered glyoxal-based resins and indeed invented permanent-press technology. Sequa's new Permafresh low-formaldehyde and no-formaldehyde formulations "perform as well as a urea formaldehyde resin, but cost is at a premium. Although the per-garment cost is small, the cost of these resins can be as much as five to six times that of the urea formaldehyde resins," Cabrey says.

Sequa considers itself a one-stop shop for textile chemicals. According to Cabrey, the company also formulates and sells a line of hydrophobic thermosetting resins and zirconium synthetic wax water repellents, polyethylene emulsion and fatty glyceride softeners, as well as flame retardants and soil repellents.

Another one-stop shop for textile chemicals is the Chem-Mark division of Ivaco, which, according to its president George D. Maynard Jr., has an annual sales volume of \$8 million. Like many of its competitors with broad-based lines

(Maynard estimates there are 30 such competitors), Chem-Mark formulates and sells durable-press resins such as its Reactex glyoxal resins. Other products include Chemweld, which keeps loose-knit fabrics from slipping and imparts a soft feel to the fabric.

Maynard agrees that the textile chemical business is a rough-and-tumble one. "Everyone of us has five to 50 unique products and 100 to 150 products that everyone else has." It's an industry that requires so many suppliers, in part, because companies have to be relatively small and agile to service very demanding fabric mills, each of which seems to require products tuned precisely to its specific needs, he says.

Chemical companies need not always have an extensive line of products to have a presence in the textile finishing area. Angus Chemical manufactures a line of permanent-press resin catalysts that aid in the curing of those resins. One, an amino hydroxy compound called DMAMP-80, which is 2-dimethyl-amino-2-methyl-1-propanol, is a slow-cure aid for easy-care resins that helps preserve fabric strength and does not tend to yellow light-colored fabrics, according to Bob Purcell, Angus product development director. The company, a specialist in the nitration of propane, also sells a faster-acting resin catalyst, amino methyl propanol.

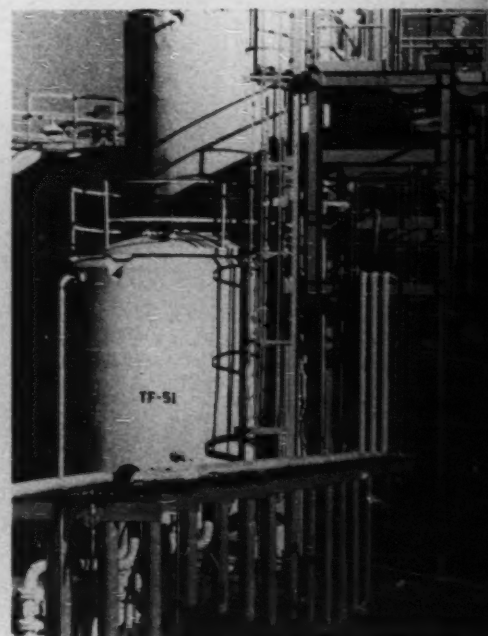
American Cyanamid is another company with a large variety of textile chemicals and a major force in permanent-press resins. The company has a captive domestic source of glyoxal; it produces the compound at its Charlotte, N.C., plant. According to Les Reynolds, American Cyanamid's manager of textile chemical business development, growth has slowed in durable press. It is a competitive business, he says, and at times the cost of new developments has limited profitability in the business. "Everybody spent a fortune developing nonformaldehyde resins. Basically, there is no cheap replacement for dimethylol dihydroxy ethylene urea resins," says Reynolds.

Because of the concern with formaldehyde fumes, Reynolds says that Cyanamid has seen a "shift in our

market to where the largest percentage of resins we sell contain glyoxals." Cyanamid sells a number of melamine and urea formulations as well.

In addition, Cyanamid sells a small line of softeners based on polyethylene emulsions, fatty acid ester blends, and silicones for use with its extensive durable-press resins line, and it has a line of water repellents and fluorochemical water-, oil-, and stain-repellent extenders. The company has re-entered the flame retardant business "after a hiatus," says Reynolds. Applied by a half-dozen small specialty finishers for industrial and military use on cotton shirts and pants, its Aerotex line of phosphine-based flame retardants show some growth potential.

Hoechst Celanese is also an important supplier of easy-care resins for textile finishing. Like Cyanamid, it, too, is basic in glyoxal, which is supplied from a Hoechst plant in France. According to Martin G. Doeleman, textile chemicals market manager for Hoechst Celanese, "We make Casurit easy-care resins and supply glyoxal to resin formulators, too. Our main objective is to be a supplier of raw material to resin manufacturers."



Sequa Chemicals' Chester, S.C., plant supplies permanent-press resins

Research now is aimed at developing faster-cure, easy-care resins to save energy and money, Doeleman says. Whereas many fabrics may have to cure now for three minutes at 300 °F, Hoechst Celanese is trying to develop resins that might cure for one minute at the same temperature, he says. Hoechst Celanese also makes a line of silicone-based softeners, and fatty acid esters also used for softening.

In addition, Hoechst Celanese is involved in a line of business—water-, soil-, and stain-repellent fluorochemicals—that is very different from the durable-press resins and softeners market. Fluorochemicals with labels such as Scotchgard from 3M and Teflon and Zepel from Du Pont are well-recognized consumer labels that compete in apparel and broadloom with Hoechst Celanese's unbranded monomer. "We supply the monomer to formulators who blend unbranded products. Their products are more

attractively priced because they lack a label and the overhead it demands," Doeleman says. Supplying both solvent and emulsion type fluorochemicals, Hoechst Celanese, like 3M and Du Pont, is basic in fluorochemical production, he says.

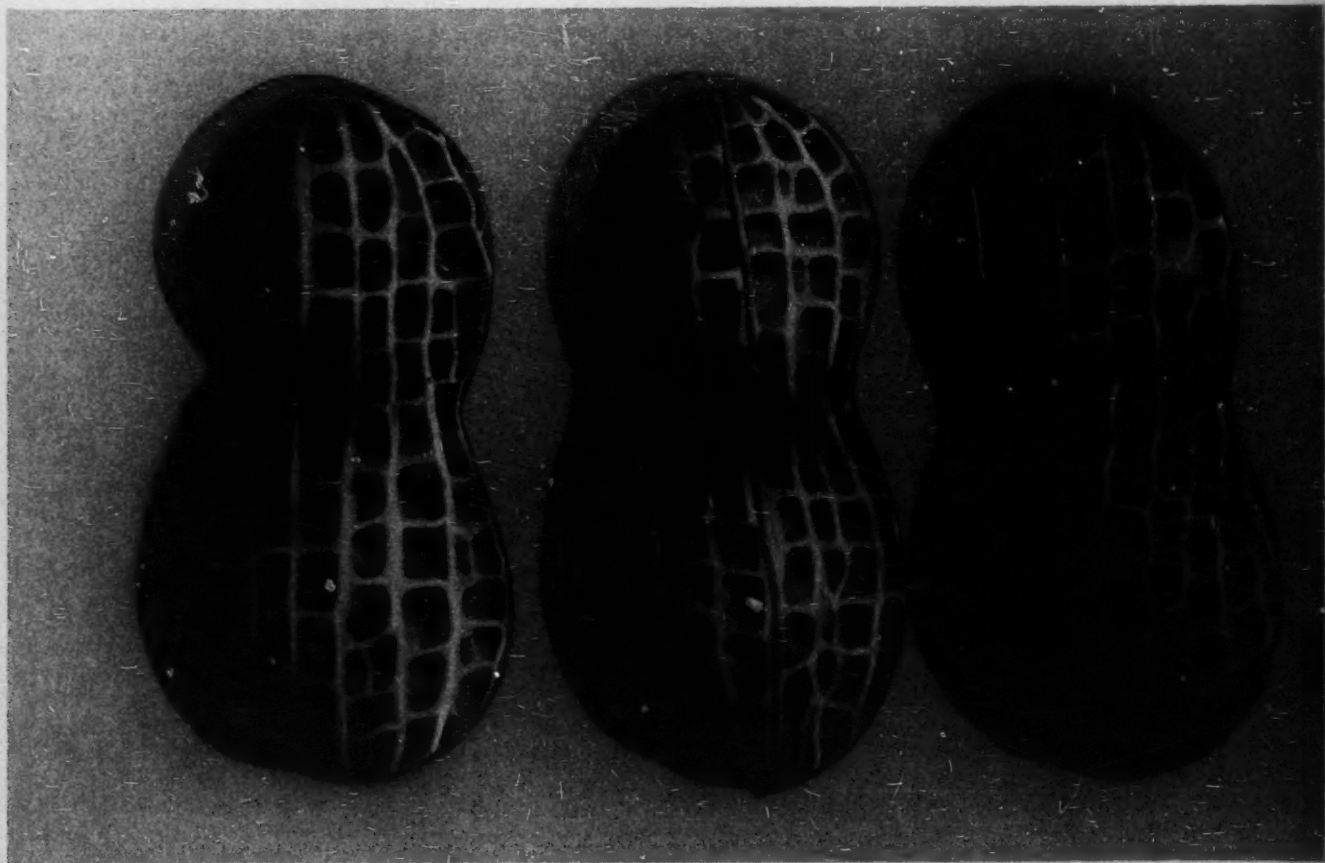
Success in the well-known brandnames is a matter of "getting the end user to specify our product," says Tom G. Gerlach, 3M's protective chemicals division marketing communications manager. It is a type of chemistry that gives obvious added value to textiles, he says, and one that the textiles consumer would be willing to pay for when he or she sees the Scotchgard tag on merchandise. 3M requires strict adherence to high-performance standards before textiles are allowed to display the Scotchgard name.

In like manner, Du Pont puts its marketing muscle behind its Teflon home fashion and Zepel apparel rain- and stain-repellent fluorochemical products. It, too, enforces

performance requirements on products carrying its labels. Advances have allowed Du Pont to develop a fluorochemical formula that will work on woolen apparel fabrics, according to John Thackrah, business manager in Du Pont's chemical and pigments department.

Du Pont creates demand for its fluorochemicals by going directly to consumers and retailers with the romance of easier care. "You can't see, smell, or touch what it does," says Du Pont merchandising and business services manager Richard Moody, "but it does cause water-based and oil-based stains to bead up so that you can blot them off before they stain a fabric." And, adds Thackrah, that "adds peace of mind to living."

Also supplying fluorochemical products to the U.S. market through a business linkup with a Japanese resource is ICI Americas, part of the U.K.'s Imperial Chemical Industries. According to Christopher A. Fergu-



Easy-care resins lead textile finishing chemicals

\$ Millions	1986 sales
Easy-care resins	\$120
Water-, oil-, and soil-repellent finishes	90
Hand modifiers and softeners	70
Flame retardants	35
Other finishes*	15
TOTAL	\$330

* Includes antistatic compounds, mildewicides, germicides, and mothproof agents. Source: Charles H. Kline & Co.

son, business manager of specialty finishes, "our fluorochemical endeavors are technological rather than merchandising." He claims ICI Americas' Milease F-14 for mainstream use and Milease F-31X for rain, ski, and outdoor wear are more durable to repeated drycleaning, and are "better mouse traps," than products from the company's other well-known competitors.

One of the small agile formulators of fluorochemical treatments for textile mills is Lindley Chemical, which, according to Thomas Lindley Jr., is widely known in the hosiery and piece goods treatment business. "We procure the fluorinated monomer and proceed from that point. Our specialty is to process the monomer to the final polymer or emulsion depending on the application method," Lindley says. The company also formulates a number of silicone softeners by processing the silicones to produce unique products, such as a silicone for foam application.

For textile softening chemicals, Union Carbide is one of the larger companies involved. According to Terry L. Lance, textiles business manager within the specialty chemicals division, "Formulators take our product and may blend it with polyethylene and fatty acid softeners. We don't blend softeners, but we sell softeners to formulators who

will mix specialties to help a mill get a special effect."

Carbide does refine its silicones, thereby producing products ideal for different market segments. One new product, MagnaSoft TLC, is a silicone softener designed primarily for disposable nonwoven fabrics. For instance, it makes the polypropylene fiber frequently used in diaper cover stock hydrophilic as well as softer, Lance says. Another recent product, MagnaSoft Extra, is based on new patented silicone technology, he says, and is a completely nonyellowing "super softener" aimed primarily at cotton-rich products recently popular with consumers.

In the trendy fashion fabric business, "niching products to smaller applications areas is our defense. There is not just one application for our silicone products," Lance says. Carbide is also a supplier of Carbowax polyethylene softeners to formulators, but it is a business one

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Business

Carbide spokesman characterizes as a "commodity area" that moves on price.

Du Pont's Avitone A softener is a sodium hydroxide softener that Horn characterizes as an excellent anionic softener for cotton and cotton-blend fabrics. Avitex NAR is a higher alkyl amine softener for use on fabrics composed entirely of synthetic fibers. "These products don't replace silicones or polyethylene," says Horn. "They give a different hand and lubricity than the others." For instance, Avitone A provides a desirable feel, particularly to cotton terry cloth, he adds.

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Formulators that combine ingredients to form fabric finishes include specialists such as Burlington Chemical (which is not associated with the huge fabric mill Burlington Industries). According to Sam B. Moore, vice president of research and development, Burlington Chemical makes a number of fatty acid-based softeners as well as polyethylene and silicone softeners. A challenge for the company now is to come up with finishing formulations, particularly softeners, that will allow garment manufacturers to dye garments after they are cut and sewn. Such a technological success would enable manufacturers to hold down inventories while still delivering garments more quickly to retail outlets in the colors most in demand.

Another formulator of softeners is Sandoz, best known as a powerhouse in the textile-dyeing business. Its softeners include a silicone elastomer finish, Sandoperm FE, that is blended with a catalyst and cross-linker for a smooth elastic finish on knit fabrics. A hydrophilic silicone softener, Silsmooth VEL, offers more

comfort in cotton and cotton-blend fabrics, and cationic fatty acid softeners, Ceranine HCA for cotton and Ceranine PNL for synthetics, offer the unique soft hand and bulk of cationics and contribute minimally to the yellowing of fabrics, the company says.

Another basic silicone supplier who keeps a close eye on the textiles market is Dow Corning. It markets a line of products that formulators buy and tailor to an individual mill's requirements, according to Richard W. Awe, associate development scientist for Dow Corning. It also supplies an emulsion silicone formulation for softening, Dow Corning SSW emulsion, which a mill can apply directly in finishing.

An advantage of the silicone softeners is that they make fabric woven from coarse yarn spun on new, highly efficient open-end spinning equipment more acceptable, Awe says. And though silicone softeners are premium-priced softeners that produce "much smoother and softer fabrics than polyethylene-treated fabrics," their cost may be justified on new fabrics woven of open-end spun yarns, he says.

In addition, Dow Corning markets antimicrobial agents for socks, hosiery, carpet, and nonwovens also based on silicone technology. The company is one of the better-known suppliers of antimicrobial agents, sold under the Sylgard trademark, Awe claims.

An equally known, if not better-known, supplier of antimicrobial textile treatments is Sanitized. The company is headed by Stewart E. Klein, a micropaleontologist whose knowledge of chemistry and interest in a 50-year-old family business selling antimicrobial textile treatments led to his most recent discovery of an antimicrobial agent composed of certain silyl quaternary ammonium salts. His patent on these salts is one of many Sanitized holds, Klein says.

Products of Sanitized are distributed in the U.S. by Sandoz. A key to the success of the company, according to Klein, is its large-scale, quality-control testing of fabrics incorporating Sanitized products by independent laboratories. That, together with efforts to convince mass

merchants to specify Sanitized products, is another important element in the company's marketing success, he says.

Interest in the consumer market in cotton-rich and all-cotton fabrics has led to increased institutional interest in cotton for uniforms in hotels, motels, and hospitals as well as in the defense industry. Fabrics for institutional use must be flame retardant. Albright & Wilson, a U.K.-based company with U.S. operations owned by Tenneco, sells a phosphonium-type flame-retardant material to treat 100% cotton chambray shirts, denim pants, and workwear, according to Glenn W. Holden, product manager. Its formulation is sold under the names Proban and Retardol.

Another flame retardant, Antiblaze, treats 100% polyester and nylon drapery, window shades, and curtains for institutional use with a phosphorus-based material, says Holden. He sees growth in flame

retardant treatments propelled mostly by legislation in several states that require flame-retardant textiles, particularly in public places.

White Chemical, which emphasizes bromine-based flame retardants, aims its products at upholstery and automotive finishes as well as heavy industrial protective clothing. According to Charles E. White, flame retardant marketing manager, 5-oz-weight shirting fabrics treated with White's compounds withstand a molten aluminum splash and will not burn the person wearing the fabric because the treated fabric will not transfer heat.

"We're not trying to sell a drum of soapy water," emphasizes White, explaining the complexity of the textile chemical business in general and the technological attention and support required of his company's flame-retardant chemicals in particular. There are, he says, "a lot of specialized system applications in the textile business." □

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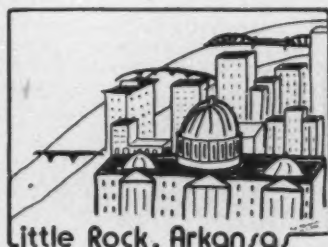


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Scientific techniques prove
"ancient" ceramics are fake
Page 28

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CHEMICAL & ENGINEERING

NEWS

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Growth seems to falter
Page 33

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News of the Week

■ American Medical Association and Senate bill join recent calls for comprehensive national effort for the control and prevention of AIDS. **Page 6**

■ Supreme Court decision striking down Louisiana's 1981 creationism law is met by elation, relief, and caution in the scientific community. **Page 7**

■ Dainippon Ink & Chemicals offers to buy Reichhold Chemicals, in a deal that would be worth \$473 million. **Page 8**

■ Colorado likely will become first state to restrict gasoline use, as it attempts to comply with Clean Air Act's carbon monoxide standard. **Page 8**

■ A number of chemists were among recipients of national science and technology medals, the nation's highest honor for achievements in science, which were awarded by President Reagan last week. **Page 8**

Letters	4
Editor's Page	5

Concentrates	
Business	9
Government	15
Science/Technology	22

The Departments	
ACS Focus	44
New Products	53
Newscripts	68

Business

Matheson Gas Products, founder of the U.S. specialty gases industry, reorganizes its operation in effort to regain its sales leadership. **Page 11**

Market for silicone fluids, which are used as replacements for PCB-containing fluids in electric transformers, remains strong. **Page 12**

Wellman, a small, successful fibers producer, decides to go public with an offering of 4.9 million common shares. **Page 14**

Government

Falsification of drug reports at Federal Aviation Administration lab brings new cries against increased drug testing of federal workers. **Page 19**

Private-sector whistle-blowers on health and safety issues need stronger and more consistent federal protection, says government report. **Page 20**

Science

The search for drugs to retard AIDS virus is yielding a wide variety of chemical substances, some of which show promise. **Page 25**

Technology

Thermoluminescence technique, used to date ceramics, exposes pieces long thought to be pre-Columbian as modern. **Page 28**



Salary Survey

Unemployment among chemists was down last year; however, median salaries surprisingly showed little or no growth. **Page 33**

people closer to customer locations. Prospects for distributorships include welding supply companies that now sell industrial gases. Such companies may welcome opportunities to expand beyond their declining industrial accounts to reach high-technology firms, hospitals, and universities.

Matheson will show new distributors how to store, ship, and use specialty gases. Matheson salespeople will join those of distributors in calls on new customers. And the firm will license its technology for repackaging of specialty gases to distributors, thus giving them a share of profits from this value-added step.

In addition to this transfer of technology, Matheson will give customers the benefits of its experience in handling specialty gases. For example, Matheson's experience in destroying toxic gases may be valuable to customers whose process effluents contain such gases. In partic-

ular, the company has developed canisters to destroy gases catalytically, thus replacing alternative scrubbing techniques. Matheson also has developed personnel exposure monitors, leak detectors, and remote gas-sensing devices.

Matheson will offer a variation of its in-house computer program used to keep track of cylinder serial numbers, contents, batch numbers, and shipping histories over the past few decades. The program is available on diskettes that operate on IBM-PC microcomputers. Data from the program can be transferred to Lotus 1-2-3 or dBase.

In an expansion of its product line, Matheson acquired Isotec of Centerville, Ohio, in 1986. Isotec produces stable isotopes of carbon, nitrogen, oxygen, and the rare gases by cryogenic fractionation. These isotopes are useful as tracers and in manufacture of radiopharmaceuticals.

Stephen Stinson, New York

Market for silicone PCB substitutes stays large

When Congress passed the Toxic Substances Control Act of 1976 (TSCA), it set into place a national mandate to eliminate the use of polychlorinated biphenyls (PCBs). And at a recent seminar for the press in New York City, Dow Corning, one of three primary producers of silicone fluid replacements for PCB-containing dielectric fluids in electric transformers, presented expert opinion and testimony regarding the legal, practical, and scientific rationale for replacing PCB fluids with silicones.

PCBs have been implicated as a cause of human skin and liver disease, and of cancer and birth defects in laboratory animals. They persist in the environment and tend to concentrate in living tissue.

TSCA "is the first and only time that Congress has identified a specific compound in environmental law," Jack Pulley, Dow Corning's managing counsel of administrative law, told the seminar. As a result, "PCBs have become the focus of more regulatory attention than any other compounds in history. The Environmental Protection Agency

and other federal agencies have touched on PCBs 190 times during the past three and a half years alone," Pulley said.

Transformer owners who fail to follow the confusing array of regulations regarding servicing of existing PCB-containing equipment or the removal and proper disposal of PCBs from units being taken out of service are subject to "civil penalties of up to \$25,000 per day of violation and criminal sanctions of up to one year in jail per day of violation," according to Pulley.

The replacement of PCB-containing equipment has turned into a substantial business for the manufacturers of replacement fluids with good dielectric properties in wet-type transformers. And according to William C. Page, a senior product market specialist with Dow Corning, that has meant that about 45,000 PCB-containing transformers have been replaced since the first commercial sales of silicone dielectric fluids for transformers began some 13 years ago.

With an average of 230 to 300 gal of dielectric fluid contained in an

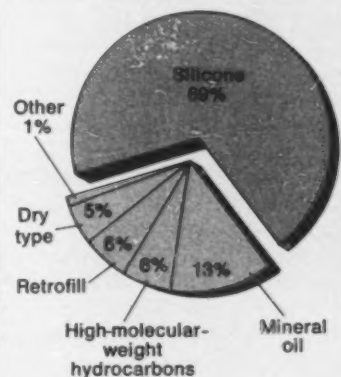
average transformer, that has meant that since 1974 Dow Corning, Union Carbide, and General Electric have supplied 10.4 million to 13.5 million gal of silicone-type fluids as either direct replacements in PCB-contaminated units or for use in new transformers.

Dow Corning believes the supply of silicone dielectric fluids required to supply replacements of PCB-containing transformers in the next few years is about twice as large as the industry has already seen, said Page. Dow's own silicone fluid for transformers is DC 561, a trimethyl end-blocked polydimethyl siloxane fluid.

Of the four major markets for silicone dielectric transformer fluids, Page said he believes that electrical utility changeover has crested and is on its way down because EPA guidelines have made it mandatory for the utilities to act first. A huge market for replacement of transformers in government facilities is only now beginning to grow, whereas the market for replacing transformers in industrial settings might not take off until much later, he said. The number of installations required because of new construction is relatively small, Page said.

Among the outside consultants Dow Corning tapped at its press seminar, Harry Onishi, an engineer-

Silicone tops replacements for PCBs in transformers



Total number of cases
1985 = 10,511*

* Replacements for PCB-containing transformer fluids in electric utility power grids.
Source: Dow Corning

ing manager for Commonwealth Edison of Chicago, said that company has embarked on a \$250 million program designed to end the utility's dependence on PCB-containing transformers. Of a total 2400 units containing PCBs in the utility's system, more than 900 units containing silicone dielectric fluid had been installed by April this year.

Commonwealth Edison and other utilities made an industrywide effort to investigate replacements for PCB-containing transformers. The most likely replacements, Onishi said, were "silicone oil transformers, hydrogenated paraffin oil transformers, gas cooled or dry-type transformers, mineral oil transformers, and perchlorethylene transformers." He added that "silicone oil exhibited very acceptable fire-resistant properties during staged catastrophic-fire tests, and its electrical properties and operating requirements do not place undue or unique demands on users." Onishi estimated that industrywide, utilities would be spending billions of dollars to make the switchover mostly to silicone-containing transformers.

According to Eric T. Naschold Jr., an electrical engineer and partner in the Roanoke, Va., consulting firm Hayes, Seay, Mattern & Mattern, if a client decides to replace a PCB-containing transformer, he has a number of options. Standard mineral oil units are a good choice for locations with suitable fireproof vaults, said Naschold, who has worked closely with a number of government agencies in the Washington, D.C., area.

Some customers, he said, opt for dry-type transformers at costs generally lower than those for liquid transformers. "However, standard dry-type transformers are not suitable for use outdoors or in dirty locations and do not provide the same degree of insulation associated with standard liquid transformers," Naschold added that higher-cost, more sophisticated dry transformers do have applications in dirty locations and where high overload capacity is required, though he admitted that operating costs for these units can be 1.5 times greater than such costs for liquid transformers.

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Unemployment Is Down This Year for Chemists

Salaries seem to show little or no growth from a year ago when looked at broadly, but the lack of gain may be more apparent than real so far as individuals are concerned

The good news from this year's survey by the American Chemical Society of the economic status of its members: Unemployment among chemists is about a third lower than it was a year ago. As of last March, only 1.1% of ACS chemists were jobless but looking for work, down from 1.7% in March 1986. The rate of unemployment has not been so low since 1981, and the only year since 1971 that it has been lower is 1980, when it fell to 0.9%. Unemployment is about equally down

across the board—for both men and women, and both minority and nonminority individuals, as well as for holders of B.S., M.S., and Ph.D. degrees.

The surprising news from the survey: Salaries, overall, seem little, if at all, changed this year from a year ago. The median salary reported by chemists who hold no more than an undergraduate degree is only 2% higher than in 1986; that for chemists with an M.S. is up 3%. For both, the increase is relatively slight, com-

pared with previous gains over the past couple of decades. Even more unusual, the median salary for Ph.D. chemists is essentially unchanged, as is that for all chemists whatever their degree. Such a result is unprecedented in the nearly 20 years that ACS has been making similar annual surveys of members' salaries. Previously, the median salaries of Ph.D.s had grown steadily throughout two decades.

Because growth in salaries apparently has hit a snag, chemists gen-

Unemployment is low for all ACS members, and especially so for those with Ph.D.s

Employment status ^a	Chemists								Chemical engineers	All members ^c
	Total	By sex		By highest degree			By minority status			
		Men	Women	B.S.	M.S.	Ph.D.	Minority ^b	Nonminority		
Employed full time	94.4%	95.4%	89.3%	94.9%	94.6%	94.1%	92.7%	94.6%	93.9%	94.0%
Employed part time	1.5	1.1	3.6	1.6	2.1	1.3	1.2	1.5	2.1	1.6
Postdoctoral or fellowship	2.0	1.7	3.0	0.3	0.1	3.2	4.5	1.7	0.4	1.7
Unemployed										
Seeking employment	1.1	1.0	1.5	1.7	1.3	0.8	1.3	1.1	1.6	1.4
Not seeking employment	1.0	0.7	2.6	1.5	1.9	0.6	0.3	1.1	2.0	1.2

^a As of March 1, 1987. ^b Black, Hispanic, American Indian, Alaskan native, Asian, Pacific Islander, or other. ^c Includes ACS members whose highest degree and present work are in neither chemistry nor chemical engineering. Source: ACS survey

Increases in salaries for chemists were subpar or nonexistent last year

\$ Thousands	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	Annual change		
												1986-87	1982-87	1977-87
CHEMISTS' MEDIAN SALARIES ^a														
B.S.	\$33.5	\$33.0	\$32.0	\$30.9	\$30.0	\$28.5	\$27.5	\$25.0	\$23.5	\$22.0	\$21.0	2%	3%	5%
M.S.	39.0	37.9	36.0	34.0	33.0	31.6	30.0	26.0	25.0	24.0	22.0	3	4	6
Ph.D.	47.7	47.8	44.0	42.0	40.0	37.5	35.0	31.2	29.0	27.4	26.0	0	5	6
All chemists	42.5	42.5	40.0	38.0	36.0	34.7	32.0	28.9	na	na	na	0	4	na

^a Base annual salary as of March 1, 1987. na = not available. Source: ACS survey

An increase in responsibility brings its rewards

The amount of responsibility that chemists exert in doing their work is likely to be reflected in how much they are paid.

This year, for the first time, the annual economic survey of ACS members included a battery of questions designed to indicate the degree of responsibility with which individual respondents perform their assignments. Responsibilities were grouped into four categories: duties (the complexity of projects undertaken), technical decisions and recommendations (the scope of responsibility for technical matters handled), the amount of supervision received, and the amount of supervision exercised.

Respondents were asked to rank the level of responsibility they exercised within each of these categories on a scale of one to five, with one being the level of least responsibility. Thus, the overall level of an individual respondent's responsibility can be ranked on a scale from four (scoring one for each of the four responsibility categories) to 20 (scoring five for each of the four categories).

A chemist with a score of four, for example, works only on simple projects or in assisting senior staff, makes decisions regarding only minor technical details, works under detailed instructions and close guidance, and has no authority over others' work. At the other end of the scale, a chemist with a score of 20 has full managerial authority over an operation, including budgeting and long-term planning, has full responsibility for projects, including the authority to delegate responsibility to others, is unsupervised except within broad organizational policy guidelines, and has full control over senior staff who, in turn, may have authority over smaller groups of employees.

A chemist with a midrange responsibility score of 12 typically plans and handles projects of moderate complexity, is responsible for the technical aspects of these projects with only occasional review for effectiveness, is assigned only broad objectives and priorities for projects, and supervises a group of professional subordinates and technicians.

As the accompanying table—which pertains only to chemists working in private industry—indicates, increased responsibility clearly pays off with increased income. Among chemists whose highest degree is a B.S., the median salary of those in the top range of responsibility scores is double that of those in the bottom range, for example. Ph.D. chemists in the top range similarly have a 60% salary advantage over those at the bottom. Very few Ph.D.s, however, rank at that low level.

As might be expected, in fact, the responsibility rankings of chemists with a Ph.D. tend to be well above those of their colleagues who lack a Ph.D.; 55% have a score higher than 12, compared with only 42% of those with an M.S. and 38% of those with no higher degree than a B.S. The difference in scores between M.S. and B.S. chemists, though, is only slightly to the advantage of those with the higher degree.

The table also indicates that women chemists are considerably less likely than men to hold down a highly

Length of experience is a bigger factor in determining salary early in a chemist's career

Years since B.S. degree	Median salary (\$ thousands)*										Overall	
	0 to 1	2 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 or more		
NONACADEMIC CHEMISTS												
B.S.												
90%	\$28.5	\$31.2	\$38.0	\$46.6	\$53.5	\$58.0	\$60.0	\$67.6	\$70.8	\$56.0	\$54.0	
75%	25.0	28.0	35.0	40.1	45.0	52.0	53.0	58.9	59.5	51.0	44.0	
50%	23.0	25.0	30.0	34.5	39.0	43.0	45.4	48.0	50.0	42.0	34.0	
25%	18.7	21.3	25.5	30.0	33.0	35.0	39.0	42.1	40.0	33.0	27.0	
10%	18.0	18.1	22.0	26.0	28.0	29.0	30.3	33.3	33.2	24.0	22.3	
M.S.												
90%	—	39.5	40.0	48.3	58.5	62.4	70.0	66.0	84.0	95.0	61.3	
75%	—	32.5	35.0	43.0	50.0	52.7	61.5	58.0	64.9	62.5	50.0	
50%	—	29.0	31.2	37.5	42.7	44.7	50.0	48.5	52.5	53.0	40.8	
25%	—	24.0	27.4	32.0	35.5	37.9	42.5	39.0	41.6	48.5	32.5	
10%	—	22.0	23.5	28.0	31.1	30.0	37.5	32.0	32.6	38.0	27.5	
Ph.D.												
90%	—	—	47.0	55.0	65.0	74.0	87.0	89.4	92.5	80.0	75.0	
75%	—	—	43.0	50.1	58.7	65.0	70.5	73.0	76.0	73.4	62.4	
50%	—	—	40.3	45.0	52.0	56.0	60.0	60.7	63.5	60.0	52.0	
25%	—	—	38.0	40.7	45.0	49.0	51.6	50.5	52.0	51.7	43.7	
10%	—	—	35.4	37.1	40.0	42.0	44.6	44.6	44.8	40.0	39.0	

* As of March 1, 1987. How to read this table: Using, as an example, nonacademic B.S. chemists two to four years after having received their B.S. degree, 90% of these chemists have annual base salaries of \$31,200 or less, 75% have annual base salaries of \$28,000 or less, 50% have annual base salaries of \$25,000 or less, 25% have annual base salaries of \$21,300 or less, and 10% have annual base salaries of \$18,100 or less. Source: ACS survey

Salaries increase markedly with level of responsibility

Responsibility score	% with score			Median salary (\$ thousands)		
	All chemists	Men	Women	All chemists	Men	Women
CHEMISTS EMPLOYED FULL TIME IN INDUSTRY						
B.S.						
4 to 8	16%	14%	25%	\$26.0	\$26.0	\$26.2
9 to 12	46	44	53	33.0	35.0	30.0
13 to 16	27	29	20	40.0	40.0	35.0
17 to 20	11	14	2	52.2	53.0	35.0
M.S.						
4 to 8	12	11	18	32.0	32.0	32.5
9 to 12	46	44	53	38.5	40.3	34.2
13 to 16	30	31	26	46.0	48.0	43.0
17 to 20	12	14	3	58.4	58.8	55.0
Ph.D.						
4 to 8	3	3	6	42.5	42.6	41.2
9 to 12	42	41	53	47.0	48.0	42.0
13 to 16	39	39	37	55.0	55.0	47.0
17 to 20	16	17	4	67.5	68.0	60.1

Source: ACS survey

responsible post. A mere 3% of the women responding to the ACS survey indicate they hold jobs with a score higher than 17, compared with 16% for men. On the other hand, 18% of the women but just 7% of the men have scores less than 8. This may, at least in part, explain why salaries for

women chemists tend to be lower than those for men.

One reason why women may score lower, of course, is that as a group they tend to be younger, and hence less experienced. Not surprisingly, responsibility scores rise as length of experience increases. Thus less than

erally appear to be worse off now than they were a year ago if income is compared with living costs. Although consumer prices last March were only 3% higher than a year earlier, median salaries, in constant dollars, for B.S. chemists are 1% lower and those for Ph.D.s are down 3% from March 1986. This year will be the first time since 1980 that the increase in median salary for Ph.D.s has not outpaced the rise in living costs. Median salaries for B.S. chemists, on the other hand, have been down more often than not during the past 10 years, after adjustment for inflation. Consequently, the overall median for them this year is 15% lower than it was 10 years ago.

This year's lack of growth in salaries may be more apparent than real, however, at least so far as individual chemists are concerned. A closer look at the survey results provides further insight into what may be behind the poor appearance of the broad figures. The picture certainly

is more favorable if smaller, more discrete groups are used for year-to-year salary comparisons.

For one thing, academic salaries do not seem to have fared poorly. Median salaries earned by Ph.D. chemists at universities and colleges are higher at all professorial levels—generally 5% or more—both in schools with graduate programs and in those without.

A look at median salaries of non-academic chemists, split up into smaller groups based on length of time since they received their B.S. degree, also indicates that most such groups are earning more now than a year ago. This suggests that although median salaries for nonacademic chemists overall may have shown little or no growth, the salaries of individual chemists in most cases actually have increased.

One factor that probably has depressed the overall salary medians is that this year's survey respondents, as a whole, are less experienced than respondents in 1986. For

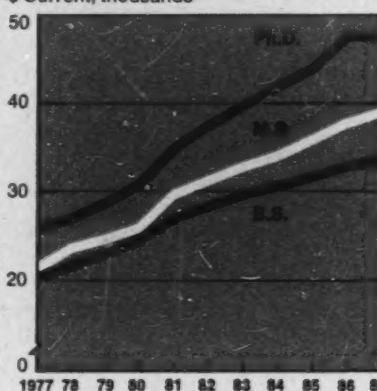
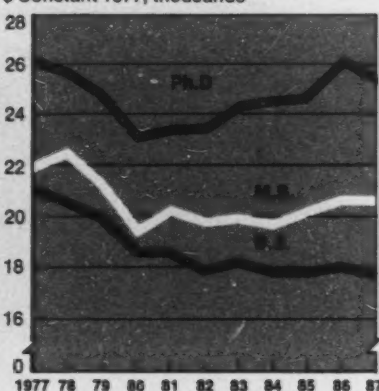
10% of the Ph.D. chemists who earned their undergraduate degree less than 20 years ago score above 16 in responsibility, but 23% of those who received their B.S. degree 30 or more years ago rank that high. Likewise for chemists whose highest degree is a B.S., only 6% of those who graduated less than 20 years ago score higher than 16, but 25% of those who received their degree 30 or more years ago rank above 16.

Even so, age and length of work experience do not appear to be the sole reason that women seem under-represented among chemists with the highest responsibility. For example, adjusting the responses from chemists with a Ph.D. for differences in length of experience, if women otherwise were as likely as men to attain a responsibility score higher than 16, approximately 12% rather than 4% would rank that high. Similarly, about 8% of women with a B.S. degree would have a responsibility score of more than 16, rather than the 2% that the survey shows. If the survey responses were weighted for differences between men and women in years of experience.

example, among chemists working in industry—where 61% are employed—19% of the respondents this year had earned their baccalaureate degree 30 or more years ago, down from 21% in 1986. At the same time, 43% of the industrial chemists in this year's survey received their B.S. in the past 14 years, up from 40% last year.

Staff reduction and early retirement programs have been widespread throughout the chemical process industries during the past two or three years as companies have strived to trim costs, divest low-profit operations, and revamp corporate structures. Older chemists often have been especially hit by these moves. This, in turn, may well account for the decrease in the numbers of older industrial chemists, who tend to have higher salaries, relative to the ranks of their younger colleagues, who are likely to earn less.

This year's survey shows no appreciable narrowing of the gap that

Growth in chemists' salaries
faltered last year...\$ Current, thousands^a^a Median base annual salary for chemists employed full time as of March 1 of each year. Source: ACS survey... especially after
adjustment for inflation\$ Constant 1977, thousands^a

generally exists between salaries earned by men and those earned by women. Because women chemists, on the average, are younger and less experienced than their male counterparts, a meaningful comparison between the two groups requires that mean salaries for wom-

en be adjusted to compensate for this age/experience bias.

When salaries are so adjusted, however, a gap—typically ranging between 10 and 20%, depending on highest degree and type of employer—still exists in favor of men. The gap, moreover, has shown no evi-

dence of narrowing in recent years. And it is just as evident for women who work for government or academic employers as for those with jobs in private industry.

As has been the case for several years, the gap between salaries of women and men chemists is quite small during the early stages of their careers. For men chemists with a B.S. and working in industry, for example, the median salary is 7% higher if they have been working for just four years or less and only 3% higher if they have been working between five and 14 years. But for B.S. industrial chemists with longer experience than that, the median for men's salaries is more than 20% higher than that for women's salaries. Similarly for Ph.D.s in industry, the difference between the median for men and that for women is very slight among those who obtained their undergraduate degree less than 20 years ago, but for those with more experience, the median for men also is more than 20% greater.

The discrepancy between salaries

Ph.D.-granting schools pay higher salaries, especially for more experienced professors

Years since B.S. degree	Median salary (\$ thousands) ^a								
	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 or more	Overall
Ph.D. CHEMISTS EMPLOYED FULL TIME IN ACADEMIA									
Ph.D.-granting schools									
Professor	—	—	\$56.9	\$54.9	\$61.0	\$62.2	\$63.4	\$68.9	\$61.0
Associate professor	—	(\$41.5)	42.0	42.0	(41.8)	—	(43.3)	—	42.0
Assistant professor	\$34.0	35.4	(36.1)	—	—	—	—	—	35.0
All ranks ^b	32.9	36.0	42.4	48.7	56.6	60.5	58.7	67.1	48.8
Non-Ph.D.-granting schools									
Professor	—	—	(43.8)	43.6	49.0	49.0	51.2	50.0	48.2
Associate professor	—	(34.2)	36.5	38.5	(37.0)	(38.4)	(39.5)	(41.2)	37.6
Assistant professor	28.1	30.5	32.2	(33.9)	—	—	—	—	30.5
All ranks ^b	27.8	30.5	35.1	40.3	46.4	48.2	49.7	47.6	41.0

Note: Where no salary data are shown, sample is too small to provide a meaningful figure; data in parentheses are from relatively small samples, as well, and should be viewed with caution. ^a As of March 1, 1987; salaries of academic chemists with nine- or 10-month contracts are adjusted to a 12-month basis. ^b Includes instructors, lecturers, research associates, and others not listed separately. Source: ACS survey

Women chemists are likely to earn less than men wherever they work

Mean salary, \$ thousands ^a	B.S.				M.S.				Ph.D.			
	All chemists	Men	Women	Women as % of men	All chemists	Men	Women	Women as % of men	All chemists	Men	Women	Women as % of men
EMPLOYER												
Private industry	\$37.4	\$39.4	\$34.3	87%	\$43.8	\$45.4	\$39.7	87%	\$55.7	\$56.4	\$49.2	87%
Academic	24.4	26.6	22.3	84	29.9	31.9	27.4	86	41.3	42.3	36.1	85
Government	34.5	36.5	30.6	84	35.9	36.8	33.7	92	50.2	50.9	41.8	82
Other	33.6	36.9	28.4	77	42.0	46.7	35.9	77	53.5	54.5	50.2	92

^a As of March 1, 1987; to facilitate comparison, women's salaries are adjusted for the difference in average length of experience between them and men. Source: ACS survey

Industrial chemists earn more if they work as managers

Years since B.S. degree	Median salary (\$ thousands) ^a											
	0 to 1	2 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 or more	Overall	
CHEMISTS EMPLOYED FULL TIME IN INDUSTRY												
Sex												
Men	B.S.	\$23.5	\$26.0	\$30.8	\$34.8	\$40.9	\$47.5	\$46.8	\$49.0	\$50.0	\$43.2	\$36.4
	M.S.	—	32.0	33.0	38.0	43.8	45.0	51.2	51.0	54.9	56.0	42.5
	Ph.D.	—	—	41.0	45.4	52.0	59.0	63.1	64.0	66.9	55.5	53.0
Women	B.S.	(22.0)	24.4	30.0	33.7	32.0	(38.7)	(39.0)	(40.5)	(47.2)	—	30.0
	M.S.	—	(27.0)	31.5	38.0	40.1	(43.8)	(45.0)	(38.0)	—	—	35.0
	Ph.D.	—	—	40.0	44.6	53.2	47.0	(51.2)	—	—	—	44.8
Work function												
General management	B.S.	—	(28.0)	35.0	(36.9)	(47.4)	(50.0)	(52.9)	(55.0)	70.6	—	45.0
	M.S.	—	—	(34.0)	(41.9)	(63.0)	—	—	—	(70.0)	—	48.5
	Ph.D.	—	—	—	—	(61.8)	(67.7)	(60.0)	—	(65.0)	—	63.5
R&D management	B.S.	—	—	(38.0)	(45.0)	(46.5)	52.2	(51.8)	(60.0)	56.1	—	50.5
	M.S.	—	—	—	44.0	(53.0)	60.0	62.0	(62.5)	(55.5)	(60.0)	55.0
	Ph.D.	—	—	(50.0)	52.0	59.2	65.5	75.5	70.0	81.5	(60.0)	65.0
Basic research	B.S.	—	24.3	29.7	(34.0)	—	—	—	—	—	—	28.0
	M.S.	—	—	32.5	(37.5)	—	(45.4)	—	—	—	—	36.0
	Ph.D.	—	—	41.0	45.0	51.2	55.5	58.0	(62.0)	(68.5)	—	48.0
Applied research^b	B.S.	(23.7)	26.4	30.0	32.0	40.0	43.5	42.0	48.3	48.4	(42.8)	33.1
	M.S.	—	(31.5)	33.1	40.0	41.6	41.0	45.1	49.0	51.1	(55.5)	40.6
	Ph.D.	—	—	40.3	44.9	49.2	54.1	60.0	59.1	62.0	(58.3)	49.0
Production^c	B.S.	(22.0)	23.0	27.5	34.0	35.5	34.0	43.0	(43.5)	(41.0)	—	31.0
	M.S.	—	(29.8)	27.4	33.5	42.0	(39.0)	(48.0)	(38.5)	—	—	35.5
	Ph.D.	—	—	(40.4)	(45.0)	(44.2)	(51.0)	—	—	—	—	46.1
Marketing^d	B.S.	—	—	33.0	37.5	(40.0)	—	(49.0)	(46.8)	(49.9)	—	42.1
	M.S.	—	—	(34.5)	(40.9)	(48.4)	(43.0)	(51.2)	—	—	—	44.2
	Ph.D.	—	—	—	(44.8)	—	(55.2)	(58.5)	—	—	—	52.0
Work specialty												
Agricultural and food chemistry	B.S.	—	—	(28.3)	(43.5)	(33.5)	—	—	—	(48.8)	—	32.3
	M.S.	—	—	(30.3)	(39.0)	(44.8)	—	—	—	—	—	42.5
	Ph.D.	—	—	—	44.1	(52.2)	(53.0)	(65.7)	—	(74.8)	—	52.8
Analytical chemistry	B.S.	(23.4)	24.5	30.0	32.0	36.4	39.9	45.7	43.2	45.0	—	32.2
	M.S.	—	(29.1)	30.4	36.5	41.0	41.0	47.3	(52.5)	(55.0)	—	38.0
	Ph.D.	—	—	41.0	45.0	52.8	56.0	60.0	59.5	62.3	—	50.0
Biochemistry	B.S.	—	—	(29.1)	—	—	—	—	—	—	—	28.7
	M.S.	—	—	—	(33.3)	—	—	—	—	—	—	36.8
	Ph.D.	—	—	(39.6)	46.0	54.0	56.0	(53.3)	(67.5)	—	—	50.0
Environmental chemistry	B.S.	—	22.5	28.0	34.4	(39.8)	(44.0)	(44.2)	—	—	—	31.0
	M.S.	—	—	(32.1)	34.1	(46.4)	—	(46.0)	—	—	—	39.5
	Ph.D.	—	—	—	(44.6)	51.0	57.8	(55.0)	(54.5)	—	—	52.0
Inorganic chemistry	B.S.	—	—	(30.1)	(43.0)	—	—	—	—	(53.5)	—	36.0
	M.S.	—	—	—	—	—	—	—	—	—	—	48.8
	Ph.D.	—	—	(40.0)	45.6	(51.0)	(62.5)	—	—	—	—	49.8
Materials science	B.S.	—	(26.9)	(34.7)	—	(53.5)	(50.2)	—	(48.2)	(56.0)	—	38.9
	M.S.	—	—	(37.5)	(41.5)	—	(47.3)	—	(49.0)	—	—	45.0
	Ph.D.	—	—	(42.0)	48.0	(55.0)	57.5	69.0	(65.5)	70.5	—	55.0
Medicinal and pharmaceutical chemistry	B.S.	—	24.2	28.6	(38.8)	(44.0)	—	—	—	—	—	32.6
	M.S.	—	—	(30.4)	(35.1)	(43.4)	—	—	(42.0)	—	—	39.5
	Ph.D.	—	—	43.0	45.3	49.0	60.0	74.0	(74.4)	(64.4)	—	52.2
Organic chemistry	B.S.	—	(26.5)	28.9	34.5	40.0	(52.0)	(50.0)	(51.5)	(50.0)	—	35.3
	M.S.	—	—	32.5	(36.0)	(41.1)	(45.8)	—	—	(70.0)	—	40.0
	Ph.D.	—	—	40.4	45.0	50.6	58.0	66.0	63.0	67.0	(67.5)	52.0
Physical chemistry	B.S.	—	—	—	—	—	—	—	—	—	—	35.0
	M.S.	—	—	—	—	—	—	—	—	—	—	46.5
	Ph.D.	—	—	(39.0)	(46.4)	56.0	56.0	(71.5)	(66.0)	(75.0)	—	56.0
Polymer chemistry	B.S.	—	26.4	32.0	36.0	(43.9)	47.2	45.2	50.0	54.3	(53.5)	40.2
	M.S.	—	—	36.0	42.5	48.0	(48.0)	(56.0)	(52.2)	(52.0)	—	46.0
	Ph.D.	—	—	40.3	45.0	52.0	59.0	60.0	60.0	63.6	(54.7)	53.0

Notes: Where no data are shown, sample is too small to provide meaningful figure; data in parentheses are from relatively small samples, as well, and should be viewed with caution.
^a As of March 1, 1987. ^b Includes development and design. ^c Includes quality control. ^d Includes purchasing, technical service, and economic evaluation. Source: ACS survey

Salary Survey

earned by men and those for women can be at least partially explained by the relatively larger number of men who hold positions of high responsibility and authority. Even when allowance is made for their younger-than-average age, women are underrepresented in such jobs, where salaries are typically the highest.

This year's decline in unemployment largely is a result of an improved situation for chemists in industry. The jobless rate for industrial chemists dropped this March to 1.4%, from 2.2% a year earlier. Employment remains relatively high

for chemists who had been working in production (1.5%) or marketing (1.3%), but nevertheless it is down markedly from last year, when the rate for both groups was 3.5%. The rock-bottom unemployment rates this year for chemists most recently employed in academia (0.8%) or in government (0.4%) are essentially unchanged from those that were reported in 1986.

Although the number of chemists who are unemployed this year is very small, many of those who are out of work have found that the search for a new job is a long one. In fact, 43% of the jobless seeking work last March had been doing so for more than six months and 22% for more than a year. Ph.D.s especially seem to take a long time to find a new position they think suitable; slightly more than half of the relatively few Ph.D. chemists who were looking for a job in March—when the unemployment rate for Ph.D. chemists was a mere 0.8%—

had been without work for more than six months.

The same is true for chemists who were unemployed any time during 1986. (This year's survey is the first to inquire whether respondents were without work any time in the previous year, rather than just at the time the survey was being made.) All told, of the chemists who were in the labor force as of last March, 9% had been jobless sometime during 1986. Women were more likely to have been unemployed than men, and chemists who do not have a graduate degree more likely than those who do.

On the other hand, chemists with a B.S. tended to obtain a new position more quickly; about 70% of them found employment in six months or less but slightly fewer than 60% of the unemployed Ph.D.s were able to obtain new work that fast.

These statistics on the current salaries and employment status of

Industrial chemists are most likely to be unemployed

	% of chemists in category	% unemployed ^a
MOST RECENT EMPLOYER		
Industry	61%	1.4%
Academic	24	0.8
Government	9	0.4
Other	6	1.0

MOST RECENT WORK FUNCTION		
R&D	46%	1.3%
Teaching	13	0.5
R&D management	12	1.0
Marketing ^b	8	1.3
General management	6	0.7
Production ^c	4	1.5
Other	12	1.7

MOST RECENT WORK SPECIALTY		
Analytical	21%	1.2%
Organic	13	0.7
Polymer	12	1.6
Biochemistry	8	0.8
Environmental	8	1.1
Physical	7	0.4
Medicinal ^d	6	0.8
Inorganic	4	0.6
Agricultural and food	4	0.7
Other chemistry	16	1.9

a As of March 1, 1987; excludes chemists who are not employed but not seeking employment. b Includes purchasing, technical service, and economic evaluation. c Includes quality control. d Includes pharmaceutical and clinical chemistry. Source: ACS survey

Oil industry offers highest salaries for industrial chemists

Industry	% of industrial chemists				Mean salary (\$ thousands) ^a		
	All chemists	B.S.	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Pharmaceuticals ^b	18%	17%	20%	17%	\$40.3	\$42.4	\$57.2
Specialty chemicals	15	13	12	16	41.8	45.7	53.3
Basic chemicals	7	4	5	9	40.8	43.8	58.2
Plastics	5	5	6	6	42.3	47.6	56.6
Petroleum and natural gas	5	3	4	6	45.1	49.4	63.6
Agricultural chemicals	4	2	4	5	37.8	46.0	54.4
Coatings	4	5	4	3	41.6	47.7	50.6
Electronics	4	3	4	4	41.2	46.2	56.9
Food	3	5	4	2	39.8	46.2	56.5
Metals and minerals	2	4	2	1	40.2	38.8	47.0
Rubber	2	3	2	2	40.7	37.8	54.7
Biochemical products	2	1	2	2	35.1	35.5	57.5
Soaps and detergents	1	1	1	2	36.3	47.2	59.8
Paper	1	1	1	1	37.2	37.8	54.8
Other manufacturing	17	20	17	16	41.2	44.1	55.1
Nonmanufacturing	10	13	12	7	40.7	41.0	50.1

a As of March 1, 1987; to facilitate comparison, mean salaries are adjusted for differences in average length of experience for each group. b Includes personal care products. Source: ACS survey

Unemployment this year has not been so low for chemists since the early 1980s

Employment status ^a	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977
Employed full time	95.4%	94.6%	95.2%	93.7%	93.5%	94.0%	95.6%	95.9%	95.0%	95.7%	95.4%
Employed part time	1.5	1.5	1.5	1.7	1.7	1.4	1.1	1.0	2.0	1.0	1.1
Postdoctoral or fellowship	2.0	2.0	1.9	2.9	2.6	2.2	2.2	2.2	1.9	1.9	2.1
Unemployed	1.1	1.7	1.4	1.7	2.2	1.5	1.1	0.9	1.1	1.4	1.5

a As of March 1, 1987; excludes chemists who are not employed but not seeking employment. Source: ACS survey

Salary Survey

Nearly 10% of chemists were unemployed sometime in 1986

% unemployed



Chemists who were unemployed last year often were jobless more than six months

Months unemployed in 1986	Less than 1	1 to 3	4 to 6	7 to 12
All chemists	9%	35%	17%	38%
Men	8	35	17	40
Women	12	37	19	32
Highest degree				
B.S.	11	37	20	32
M.S.	7	39	15	39
Ph.D.	8	32	16	43

Note: Excludes chemists not in the labor force March 1, 1987. Source: ACS survey

members of the chemical profession are based on more than 12,000 responses to a mail survey of a random sample of ACS members taken this past March by the ACS Office of Statistical Services, under the aegis of the ACS joint board-council Committee on Economic Status. The survey was limited to U.S. residents who are not students, retired, nor emeritus members and who are less than 70 years old.

Detailed results of the survey will be published by August as four separate reports: "1987 Salaries of Non-academic Chemists" (price: \$75 for ACS members, \$150 for nonmembers), "1987 Salaries of Academic Chemists" (price: \$50 with no member discount), "1987 Salaries of Nonacademic Chemical Engineers" (price: \$50 for ACS members, \$100 for nonmembers), and "1987 Employment Status and Demographic

Characteristics of ACS Members" (price: \$10 with no member discount); all four publications can be purchased at a price of \$100 for ACS members or \$200 for nonmembers. Orders should be placed with the ACS Distribution Office, Room 210, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036; ACS members should include their membership number with their orders. □

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CHEMICAL & ENGINEERING

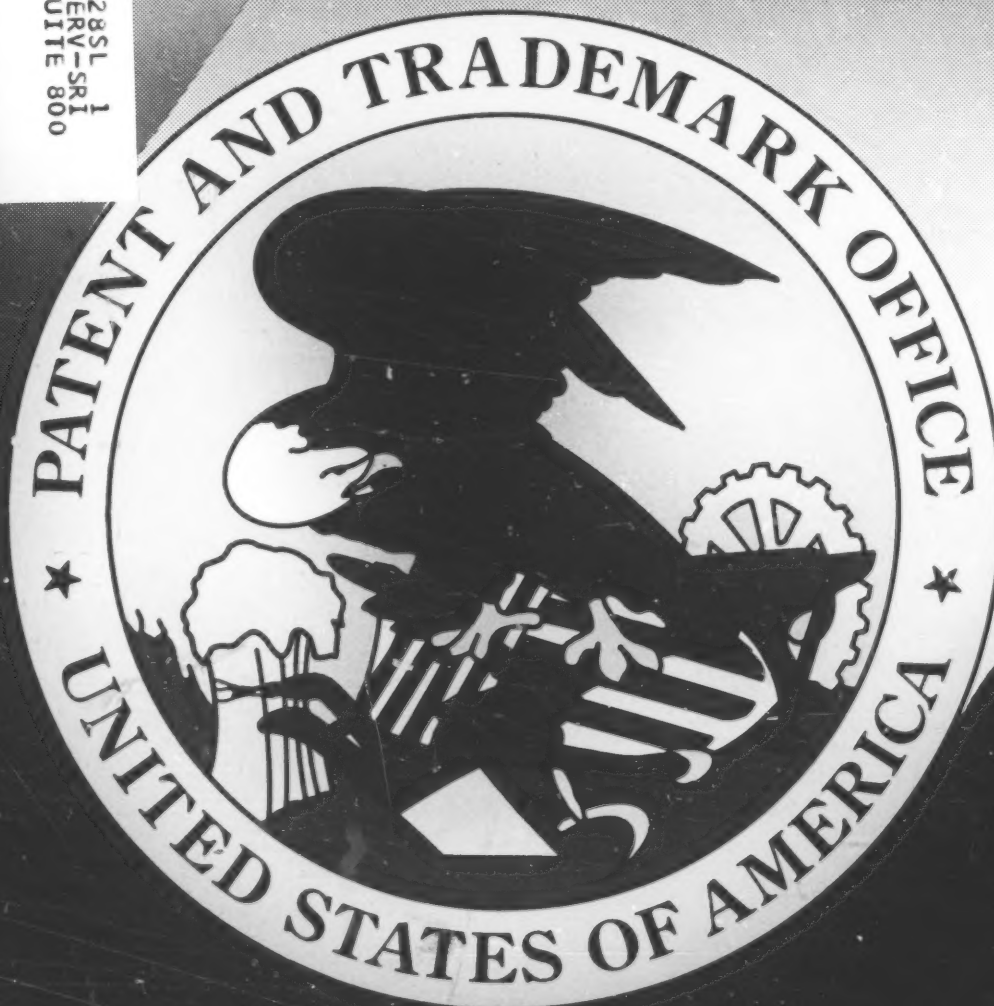
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Patent Office

Document searching is
being tested on new
computer system Page 16



News of the Week

■ Chrysler Corp. is fined a record \$1.6 million by OSHA for health and safety violations relating largely to lead, arsenic levels at its Newark, Del., auto assembly plant. **Page 4**

■ Rules to protect health care workers from occupational exposure to AIDS are urged by several workers unions. **Page 5**

■ Genentech loses its claim on human tissue plasminogen activator, in U.K. patent suit brought by Wellcome Foundation. **Page 5**

■ Mobil Chemical is presented with OSHA plant safety award. **Page 5**

■ Rorer Group bids to acquire A. H. Robins in a stock swap worth \$2.6 billion. **Page 6**

■ The American Physical Society responds vigorously to severe criticism by 39 Congressmen of its recent study of the science and technology of SDI weapons. **Page 6**

Letters	2
Editor's Page	3

Concentrates

Business	7
Government	13
Science/Technology	21

The Departments

Books	28
ACS News	30
Awards	32
People	33
Newsclips	48

Business

Demand for major industrial gases carbon dioxide, nitrogen, and oxygen is expected to rise slightly in 1987, after a flat 1986. **Page 9**

Government

Nonregulatory federal hazardous waste reduction program could help industry realize substantial savings, environmental protection. **Page 20**

Science

Low-cost photopolarimeter that characterizes polarized light in a single measurement could increase use of light polarization analyses. **Page 22**

Education

Planned electronic supplement to education journal will promote the use of microcomputers in chemical education. **Page 23**

Challenger Center for Space Science Education is advancing plans for its education program. **Page 26**

Technology

Shortest electrical pulse yet has been made and measured by scientists at IBM, makes possible the timing of extremely brief events. **Page 26**

Science Policy

European Community fails to win approval for its ambitious research and technology development program, which is now put on hold. **Page 27**



Cover Story

The U.S. Patent & Trademark Office has begun testing an enhanced computer program as it continues in its aim to become a "paperless office." **Page 16**

Demand for Major Industrial Gases Expected To Rise Slightly

If economy continues to grow, consumption of carbon dioxide, nitrogen, and oxygen will increase 2 to 3% this year following a nearly flat 1986

Bruce F. Greek, C&EN Houston

Although demand for the various major industrial gases is forecast to grow faster than in 1986, producers are facing the same problems of low capacity utilization and low profitability they did last year. Increased activity in several industries—steel, chemical, refining, and electronics—that are large users of gases are behind the modest growth. The forecast for improved demand presumes that the current higher production in those industries will continue throughout the rest of 1987.

Production of industrial gases produced by distillation of liquefied air—including argon, oxygen, nitrogen, and the tiny volumes of rare (or noble) gases—is expected to increase about 2 to 3%, nearly double the increase of last year when the business was best characterized as flat. The outlook for other industrial gases—such as carbon dioxide, helium, and hydrogen—is expected to vary widely, because the supply/demand situations vary so much for the individual gases. Of those three, only carbon dioxide is expected to be produced in smaller quantities than last year, and that's because of limited raw material supply. Helium production and demand have continued to rise relatively fast, but consumption is about 1% that of oxygen and nitrogen combined. Most hydrogen is made and consumed on-site for making methanol, ammonia, and other chemicals,

and for use in various hydro-processes, making it difficult to estimate total production accurately.

Two years of very modest demand growth for the big-volume industrial gases is bringing some longer-term changes to the industry. Many plans for capacity expansions have been put on the shelf, except for a few units whose output has been partially contracted for and their construction justified by those con-

tinued to be sufficient to reduce profitability in general. A turnaround in utilization, and in turn profitability, could occur in 1988 if the economy keeps growing at about its current pace. Changes in location of demand for industrial gases also will keep plant utilization uneven despite the few new plants being built (as in California and Florida, where added supply is needed by electronics manufacturers). In a few parts of the U.S. a tight supply could occur early in the 1990s, resulting from the lead time required to fabricate and erect an air separation plant, from the caution now introduced by slow demand growth, and from an upsurge in demand as new uses are developed.

Later, other methods of producing nitrogen and oxygen that have been in developmental stages for some time could account for appreciable shares of capacity. Two of the methods—pressure swing adsorption and membrane separation—are claimed to provide less expensive gases if only small quantities are needed and very high purity isn't required. If the cooling property of liquefied nitrogen also is needed, then these separation methods aren't usable. The economics involved in the choice of a system to supply nitrogen and oxygen on a smaller scale are complicated by costs of the equipment required. Demonstration of long-term economics of the use of these newer methods to produce industrial gases is needed. Hence, forecasts aren't available on how much of the industrial gases markets the noncryogenic production processes will take.

For some details of the near-term outlook for carbon dioxide, nitrogen, and oxygen, see the following pages.

Key Chemicals

tracts. Other existing plants whose utilization has declined could be candidates for moving to new sites. Older units, especially the high-tonnage oxygen plants located in or near steel mills, could be scrapped before the end of the decade.

As a result of new cryogenic air separation plants that have come on stream last year and this year, capacity utilization has declined nationwide. The decline has not been large, but it has been and will con-

Only carbon dioxide output will be down this year

	Carbon dioxide (millions of tons ^a)	Nitrogen (billions of cu ft)	Oxygen (billions of cu ft)
1976	b	289	389
1977	b	329	391
1978	b	380	431
1979	b	426	455
1980	b	478	431
1981	3.45	490	431
1982	3.48	482	348
1983	3.55	560	348
1984	4.21	651	387
1985	4.24	665	393
1986	4.01	671	399
1987 ^c	3.90	690	410

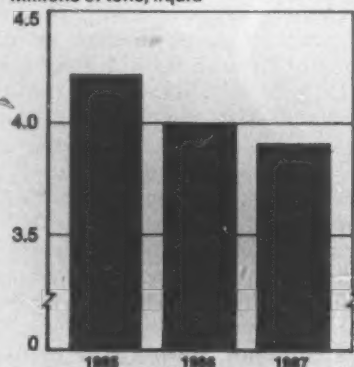
^a As liquid. ^b Comparable data not available. ^c C&EN estimate. Source: Department of Commerce

Carbon dioxide

- Demand good
- Supply limited
- Pricing firm

PRODUCTION

Millions of tons, liquid



Note: Excludes CO₂ from natural sources used directly in enhanced oil recovery.

MAJOR PRODUCERS

Airco (BOC Group); Amerigas (UGI Corp.); Carbonic Industries; Cardox division of Liquid Air; Liquid Carbonic

HOW MADE

Recovered from by-product gas streams from manufacture of ammonia, hydrogen, and ethanol by fermentation; recovered from gas streams from wells drilled to produce natural gas

MAJOR MERCHANT END USES

Freezing, chilling, and transportation of food 50%, beverage carbonation 20%, chemical manufacture 10%, metals fabrication 5%, enhanced oil recovery 5%

FOREIGN TRADE

Negligible

PRICE

\$70 per ton, but varies widely, depending on location, availability

Carbon dioxide output for merchant sale is expected to decline 2 to 5% this year to about 3.9 million tons as liquid because of limited supply of raw material—impure carbon dioxide—the cause of last year's decline. Production of carbon dioxide in 1986 amounted to 4.0 million tons, down about 200,000 tons from the year-earlier level. Capacity to produce the gas for merchant sale will remain on hold because of the difficulty in finding long-term, reliable sources of the raw material, despite strong demand and good prices in the marketplace.

Demand for merchant carbon dioxide continues to be strong as the two largest markets—food freezing and handling and beverage carbonation—grow. With the strong demand from uses that involve more than 70% of consumption, prices for carbon dioxide are remaining firm or increasing slightly. The firmer prices this year will have little or no effect on demand because the cost of carbon dioxide is a very small part of product cost.

Merchant carbon dioxide accounts for less than 20% of all carbon dioxide consumed. The larger part of consumption (some of which is captive) is accounted for by enhanced oil recovery, a technique to increase oil production from reservoirs. Carbon dioxide acts as a partial solvent for crude oil to reduce viscosity and helps to push oil from a reservoir.

The supply problem for merchant carbon dioxide producers stems from reduced ammonia output that, in turn, has resulted from a decline in fertilizer demand that traces back to lower agricultural prices. Although a large part of the coproduct carbon dioxide from ammonia production is consumed on-site for making urea, ammonia plants remain the largest source of feedstock for carbon dioxide producers.

Refineries making hydrogen needed for various hydro-processing operations are next in importance as carbon dioxide sources. Refineries currently are being run at levels higher than last

year, but availability of carbon dioxide has not increased enough to offset losses that have occurred during the closing of other refineries. With the rapid rise in production of ethanol for automotive fuel use, fermentation plants moved into third place as sources for carbon dioxide. Because of some losses of tax incentives, fermentation of corn to make ethanol for fuel uses has become a less important source for carbon dioxide. Other potential large sources of carbon dioxide, such as stack gases, remain unexploited because technology is not yet available to concentrate the carbon dioxide economically in such streams.

Even if more raw carbon dioxide were available to producers, they still would have the same competition from liquid nitrogen and mechanical refrigeration in the food freezing, chilling, and transportation use, which now accounts for about half of consumption. The cryogenic gases—carbon dioxide and nitrogen—are still considered superior to mechanical refrigeration for freezing meats and seafoods, despite advances in mechanical refrigeration aimed at minimizing dehydration and cell damage. Nitrogen competes especially well in cost at sites where oxygen demand is strong.

Despite its large base, the entire food area is forecast to remain one of the fastest growing uses of merchant carbon dioxide because of the growing demand for fast food. Institutional markets are expected to grow faster than retail markets because of the high cost of space and limited availability for frozen foods in supermarkets.

Beverage carbonation, at about 20% of carbon dioxide consumption, distantly follows food freezing and handling. This market has no competition and continues to grow at about twice gross national product, even as the baby boom slows. Soft drinks account for three fourths or more of the beverage carbonization market, with the "light" beers taking most of the remainder.

Key Chemicals

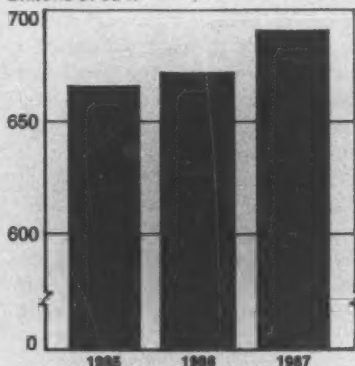


Nitrogen

- Demand up slightly
- Capacity growth minor
- Prices steady

PRODUCTION

Billions of cu ft



Note: Reported production in gaseous and liquid forms of varying purities.

MAJOR PRODUCERS

Air Products & Chemicals, Airco (BOC Group), Big Three Industries (L'Air Liquide), Liquid Air, Union Carbide's Linde division

HOW MADE

Distillation of liquefied air; pressure swing adsorption using various adsorbents; separation using membranes

MAJOR END USES

Blanketing for chemical processing 25%, enhanced oil recovery 20%, electronics manufacturing 20%, metals treating and processing 15%, food freezing 5%

FOREIGN TRADE

Negligible

PRICE

50 cents per 100 cu ft

The merchant and pipeline segments of nitrogen demand will grow in divergent patterns in 1987. Merchant demand, almost always delivered in smaller quantities than pipeline (even though merchant sometimes is delivered by pipeline), could grow twice as fast, at 4%, as the demand for pipeline. The average overall growth will range from 2 to 3%, with production of all forms reaching about 690 billion cu ft.

In terms of volume, the nitrogen delivered by pipeline dominates the business. Most pipeline nitrogen is delivered as a gas, the preferred phase for one of the largest uses—blanketing or providing an inert atmosphere for vessels and other equipment in which chemicals are manufactured. Some of the pipeline nitrogen may be produced on-site in an air separation plant adjacent to a single consumer. Depending on current economic conditions, nitrogen delivered by pipeline accounts for 65 to 75% of reported production.

The remainder of nitrogen produced and reported as an industrial gas is delivered either as liquid or as a mixture of liquid and gas. Other large quantities of nitrogen are produced by burning hydrocarbons in air to make anhydrous ammonia.

With the possible exception of enhanced oil recovery (EOR) projects, all major end uses of nitrogen will increase in demand in 1987. The two largest are as blanketing atmospheres in the manufacture of chemicals and of electronic components. Because of the varying fortunes in recent years for both of these industries, it is unclear which of them now is the larger. Various metals production and treating, EOR, blanketing in petroleum refining, and food freezing and blanketing follow in volume of consumption.

Use of nitrogen in chemical manufacture has rebounded in the past year. Consumption of nitrogen in chemical processing, however, does not relate directly to the level of capacity utilization. Nitrogen used in chemical manufacture goes to more than blanketing

of reactors and other vessels. For example, nitrogen may be used to dry reactants and products or to help regenerate catalysts and adsorbents. Prospects for growth there directly depend on expansion of chemical production capacity which, relative to the expansion of the 1970s, could be small until 1990 or later.

Nitrogen demand in electronics manufacturing is growing slower than earlier in this decade, partly because the growth is from a larger base and partly because of a slowdown in that industry. The net impact on suppliers of nitrogen, however, has been less than might be expected. As sophistication in electronic components increases, so does quality requirements of materials. Nitrogen is used both to help make materials and to preserve them as they are used. Consequently, the quality specifications for nitrogen have increased more rapidly than has demand. Consumers of nitrogen in the electronics industry have willingly paid the higher costs of better quality and improved service provided by suppliers. Strong competition is keeping prices of nitrogen level. Although the 15- to 20%-per-year growth in nitrogen going to electronics has ended, a growth rate above the average is forecast for the near term.

Use of nitrogen in making steel and in treating and fabricating various metals has grown, partially in line with the recovery in output of automobiles and various other durable goods. Despite technical developments that require more nitrogen in various small-volume treating activities, demand in metals use will grow little, probably less than 2% this year.

Other outlets for nitrogen are petroleum refining, food freezing, float glass manufacture, aerospace, aerosol packaging, and many small uses. Demand by most of these uses as a group is expected to increase slightly this year, about at the average rate for total demand of nitrogen as an industrial gas.

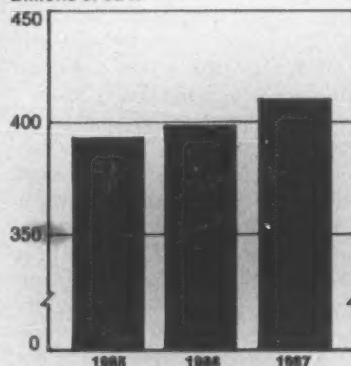


Oxygen

- **Output rise modest**
- **Capacity growth minor**
- **Pricing on hold**

PRODUCTION

Billions of cu ft.



Note: Reported production in gaseous and liquid forms of varying purities.

MAJOR PRODUCERS

Air Products & Chemicals, Airco (BOC Group), Big Three Industries (L'Air Liquide), Liquid Air, Union Carbide's Linde division

HOW MADE

Distillation of liquefied air; pressure swing adsorption using various adsorbents

MAJOR END USES

Primary metals manufacturing 55%, chemical manufacture 20%, partial oxidation processes 10%, metals fabrication 5%

FOREIGN TRADE

Negligible

PRICE

54 cents per 100 cu ft

Demand for oxygen will grow less this year than that for its coproduct, nitrogen. The lower growth remains tied to the consumption pattern for oxygen, which is dominated by steelmaking. As steel goes, so goes oxygen, because more than 50% of oxygen consumption is in steel production and fabrication.

Oxygen output in 1987 likely will increase more than it did in 1986, barring any long strike in the auto industry later in the fall. Growth this year will be about 10 billion cu ft, or 2.5% over 1986 output, for a total of 410 billion cu ft. The gain in 1986 was less than 7 billion cu ft because of a long strike in the steel industry. If 1987 production reaches the 410 billion cu ft expected, it, nevertheless, will be well below the peak output of 455 billion cu ft in 1979 and below the levels of the good years of 1978 to 1981.

Steelmaking, although staging a comeback in 1987 as a consumer of oxygen, will account for little of the growth in demand, probably less than 20% of the gain. Chemical manufacture (another resurging use) and various specialty uses of oxygen are forecast to account for most of the growth this year. The specialty uses, all of which are in the merchant market (in contrast to the pipeline or tonnage oxygen market), are the more profitable markets for oxygen.

The whole area of metals processing and fabrication accounts for more than 60% of oxygen consumption. Steel processes using oxygen enrichment start with conversion of iron ore in blast furnaces to pig iron, followed by purification to steel in basic oxygen or other furnaces. Oxygen demand for steelmaking has declined. Steelmaking alone once took more than 60% of oxygen; now it takes less than 50%. Even though technology is shifting toward more use of oxygen per ton of steel, future growth will be small.

Fabrication of metals is another slow-growth market for oxygen that is a part of the metals use of oxygen.

This use accounts for about 5% of oxygen demand. Most of the consumption is in steel cutting and welding, but significant quantities also are used in fabricating nonferrous metals.

In another area of metals processing, oxygen is used to enrich air in smelting nonferrous metal ores, especially copper. Oxygen aids this process by reducing energy requirements and by improving sulfuric acid recovery necessary to meet air pollution control requirements. The depressed demand for copper especially has held down growth in this use of oxygen during recent years.

Chemicals manufacture, at 20 to 25% of total oxygen demand, ranks as the second largest consumption area. Well over half of the oxygen consumed (and nearly 15% of total oxygen consumption) in this use goes to make ethylene oxide. Propylene oxide manufacture is a distant second, at about 10%, of oxygen consumption for chemicals. As a group, chemicals manufacture will increase oxygen consumption more than will any other category on a volume basis.

Among specialty uses of oxygen, medical and life support applications are among the fastest growing, with the rate for 1987 expected to be about 7%. The base of these uses is small, at less than 5% of total oxygen consumption. Because the quantity used is small in any single application and the number of use locations large, much equipment is required for medical uses. Although most consumption remains cryogenically produced oxygen delivered as liquid and regasified, the lower-purity oxygen from pressure swing adsorption and membrane separation is receiving more acceptance.

Other specialty uses are developing, such as pollution control processes and aerospace. As a group, those newer uses could contribute importantly to the demand increase this year. But the growth will be largely the result of resumption of engine testing in the space program.

JULY 20, 1987

CHEMICAL & ENGINEERING

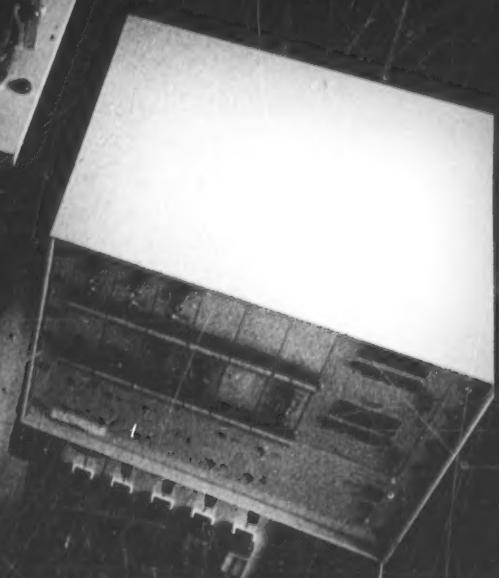
NEWS

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Mergers change face of flavors
and fragrances industry
Page 35

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Biotechnology

Major new pharmaceuticals
on verge of
commercialization
Page 11



News of the Week

■ **Controversial omnibus trade bill** contains a strong government role in speeding up commercialization of technological innovations. **Page 6**

■ **Promotion of science/technology** is key to economic growth in current Soviet reforms led by Soviet leader Mikhail Gorbachev. **Page 7**

■ **EPA withdraws fine against Lonza** for alleged violations of reporting requirements, admits it erred. **Page 7**

■ **European Community resolves** budgeting problem for its ambitious research and technology plan, which had been shelved at its most recent meeting. **Page 8**

■ **Federal court rules against Merrell Dow Pharmaceuticals** in Bendectin case and awards plaintiff \$95 million. **Page 8**

■ **Candidate nominated by petition** joins four others vying for two ACS director-at-large posts. **Page 8**

Cover: Tower fermentor for growing mammalian cells at Cetus Corp.'s Emeryville, Calif., facility

Letters **4**

Concentrates

Business **33**

Government **40**

Science/Technology **46**

The Department

Newsclips **68**

Business

Flavors and fragrances industry undergoes major changes in wake of international mergers and acquisitions. **Page 35**

The Canadian chemical industry is recording a bright performance so far in 1987, with the notable exception of fertilizers. **Page 39**

Government

Proposed legislation to explore and recover seabed resources has wide support of industry, environmental groups, and coastal states. **Page 41**

EPA sets in place indoor air quality program that will help it conduct research and give information on indoor air problems, solutions. **Page 42**

Science

AIDS drug peptide T, said to block AIDS virus from infecting human cells, has researchers vigorously debating its therapeutic potential. **Page 48**

New class of metabolites discovered in animal cells may function as intracellular messengers for various hormones. **Page 50**

ACS News

ACS Board approves 142 new or continuing Petroleum Research Fund grants totaling almost \$4 million. **Page 52**



News Focus

In the emerging biotechnology industry, a number of health care products already have been brought to market, and many more products are on the way—some with potential annual sales in the hundreds of millions of dollars. **Page 11**

Flavors and Fragrances Industry Taking On New Look

International mergers and acquisitions have produced new firms that have broader product lines and that are challenging industry leader

Patricia L. Layman, C&EN London

Some things never seem to change in the flavors and fragrances industry. Vanilla continues to be the world's most popular single flavor. Many fine fragrances are launched with great ballyhoo, but only a handful become successful. And India and China continue to loom as a great "sleeping giant" of a market, just waiting to wake and develop.

However, changes are occurring in the industry. Changes are happening in geographical activity, and in the trend of strictly chemical producers becoming more involved supplying raw materials. But most significant over the past several years has been the spate of mergers and acquisitions that are changing the face of the industry.

Observes Hans U. Daeniker, consultant with SRI International in Zurich, for example, a number of international mergers and acquisitions have taken place since SRI published his first report on flavors and fragrances in 1984. The leading merger in that year starred the same major player—Unilever's PPF International (C&EN, July 30, 1984, page 7)—as it does now.

At that time, the world's fifth largest flavors and fragrances supplier, PPF International, based in the U.K., announced that it was acquiring the 10th largest producer, Norda of the U.S. That deal made the combination a potent number three in the marketplace.

PPF has jumped back into the merger news, joining forces with Dutch producer Naarden International, in a venture called Quest International (C&EN, July 6, page 16). The combination is now the second largest supplier worldwide, challenging hard the market leader International Flavors & Fragrances, of New York City.

"PPF is determined to fuse this together, even giving it the new name Quest," says Daeniker, who has just completed a revised report on the industry for SRI. "When it bought Norda, it gave the company a better holding in the U.S., and I thought it a good move. But now, it adds Naarden, which has almost doubled [its size.] It is now clearly number two in the world."

Although the PPF-Naarden merger was the most spectacular for the industry, it has not been the only one. For example, U.K.-based Pauls Flavours & Fragrances (the old Pauls

& White's Co.), a subsidiary of the Pauls holding company, last September merged with U.S.-based Felton International. The new company is named Felton Worldwide.

Pauls was mainly in the snack flavorings business, and was certainly smaller than Felton. Felton gave Pauls strength in the U.S. and a broadened product line, as well as the R&D resources to pursue its work in templar essential oils, extracting natural materials with supercritical gases such as liquid carbon dioxide.

Companies in other countries also are actively acquiring, merging, or consolidating. Daeniker notes that in France, in Grasse, the historical center of the industry that has seen good fortune slip away, those companies that have survived "are waking up. The French companies that used to be primarily essential oils and fragrances suppliers are becoming very active in the U.S., and

Top 15 firms share half the world market

Company/parent	Headquarters	Sales (\$ million)	% of world total
International Flavors & Fragrances	U.S.	\$ 522.5	8.5%
Quest International* (Unilever)	U.K., Netherlands	396.0	7.2
Givaudan (Hoffmann-La Roche)	Switzerland	319.0	5.8
Firmenich	Switzerland	236.5	4.3
Heermann & Reimer (Bayer)	West Germany	176.0	3.2
Fritzsche Dodge & Oicott (BASF)	U.S.	146.5	2.7
Rush Boake Allen (Union Carbide)	U.K., U.S.	137.5	2.5
Floresynth-Lautier	U.S.	137.5	2.5
Takasago Perfumery	Japan	121.0	2.2
Dragoco Gerberding	West Germany	104.5	1.9
Universal Group (Universal Foods)	U.S.	99.0	1.8
Felton Worldwide* (Pauls plc)	U.K., U.S.	99.0	1.8
PFW Division (Hercules)	U.S.	86.0	1.6
Houze Bertrand Dupont (Hoffmann-La Roche)	France	86.0	1.6
T. Hasegawa	Japan	82.5	1.5
TOTAL		\$2756.5	56.1%

* Formerly PPF/Naarden, & Formerly Pauls/White. Sources: SRI International, C&EN estimates

Business

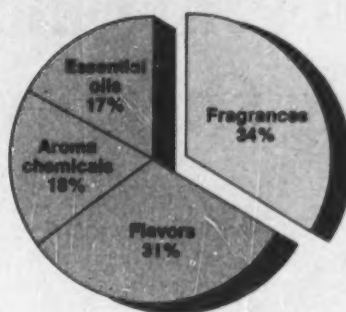
are becoming very active in flavors. It is the proper thing to do if they want to become a prominent house."

More and more, he adds, a prominent supplier must be active in at least several of the four major product categories that make up the industry: essential oils and other natural products, aroma chemicals, fragrance compositions, and flavor compositions.

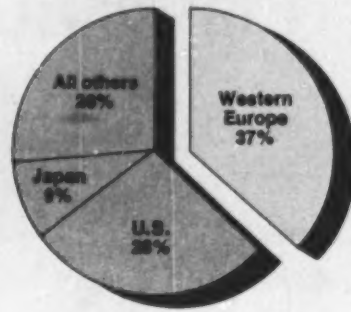
The first two categories primarily provide raw materials for the last two, used by the flavors and fragrances customer to impart odor or aroma to its consumer products. However, essential oils per se also are used as fragrances and, in some cases, aroma chemicals may be applied as such (for example, vanillin and menthol). Most big flavors and fragrances companies are involved in all four categories.

Worldwide sales of flavors and fragrances in 1985 were \$5.26 billion. Of those sales, 18% were in

Fragrances account for a third of total market...



...with Western Europe taking the largest share



Total sales 1986 = \$5.5 billion

Source: SRI International

aroma chemicals, 17% in essential oils and other natural products, 34% in fragrance compositions, and 31% in flavor compositions, according to the new SRI report. The total probably grew about 3 to 5% in constant dollars to about \$5.5 billion last year. Western Europe accounts for 37% of total worldwide sales, followed by the U.S. at 28%, Japan 9%, Latin America 8%, Eastern Europe about 5%, and all the other countries and regions 13%.

It is a disparate industry. At least 1000 flavors and fragrances companies operate worldwide, and of these, 350 to 400 have major importance. Fifteen multinational companies share about half the worldwide market.

The profitability of the industry used to be very interesting, Daeniker says, "and still is today, but only for a few companies. Many companies show only an average financial performance, and a few are even in difficulties. Good earnings have to be fought for, as in any other specialty chemical industry."

An effort to improve worldwide strength, for example, was one of the factors influencing PPF to seek a merger with Naarden—worldwide coverage, and strength from sheer size.

For Jean-Pierre Guepin, the chairman of newly formed Quest International, there was a very compelling reason for combining Naarden and PPF. "Until about a year ago," he says, "both companies had independently grown to their existing

individual sizes. Naarden and PPF had been growing faster than the market, and we had reached an equal size—probably too small to survive in an environment that was growing more and more competitive."

Now, he says, "The world will not be able to sidestep Quest International," with its group gross sales in 1986 of about \$600 million.

Charles Miller Smith, corporate president, says that "during the preparations of this merger, we acted as if Quest International already had existed for many years. Both organizations have been active in the same marketplace, but there were differences. We analyzed our assets and realized that together we will

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Guepin: compelling reason for merger

have a tremendous amount to offer our clients. Our people are spread around the world, are international, and of a very high quality."

Moreover, he adds, "In size, we are almost the largest business in the industry at this moment." His ultimate goal: "In a few years, we will have established Quest as a leading force—and by the 1990s premier within the industry of fragrances, flavors, and food ingredients."

The current holder of that position, IFF, won't let go easily, predicts Daeniker, who believes that the most remarkable company in the industry "continues to be IFF. It is the uncontested leader in nearly all continents, although PPF is larger in flavors in Europe. And, in terms of profits, IFF is on top, with 14 to 15% net earnings to sales for the past 10 years."

IFF, he believes, owes part of its strength to its pioneering spirit. "The people there take up new ideas and do things with them. For ex-



Smith: almost the largest business

ample, they have an active program with research into sex related to odor. There is a relation; they are investigating beyond the nonsense written. IFF is also looking at the relation between foods and flavors,

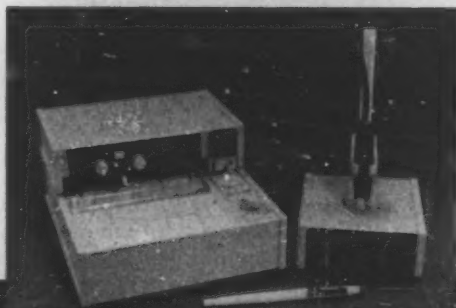
with regard to the hunger situation in the Third World, and at fragrances in plastics, now a small business, \$20 million to \$30 million worldwide."

Daeniker also cites another more subtle but critical reason IFF has done so well—"excellent and long-lasting leadership. There is a continuity in senior management, [which is] very important because relations between customer and producer are so important. It is also very important because it leads to more stable policies—more continuity."

As for the other major companies in the industry, he sees Firmenich, based in Switzerland, and the U.S.-French company Florasynth-Lautier as the big leaders in fine fragrances. He finds Firmenich a particularly interesting company. "The people there are happy. Profits are good. This impresses me—it is a good company. And Florasynth is tremendously successful."

On the other hand, Daeniker be-

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Business

believes that Switzerland's Givaudan "could be better if it were more aggressive, and more stable in personnel. It has had six top managers in 25 years. In the flavors and fragrances industry, this is not good."

China is increasing its share in raw materials—essential oils, and now, chemicals as well. Taiwan and South Korea also are coming up. The other Asian countries, especially Indonesia, are waiting around the corner. In 15 to 20 years, "these countries will have an important share of the essential oils and raw materials market," Daeniker predicts.

As it stands, the U.S. is the leading supplier of essential oils, followed by China and Brazil. Eastern Europe supplies about \$25 million of essential oils each year to the West.

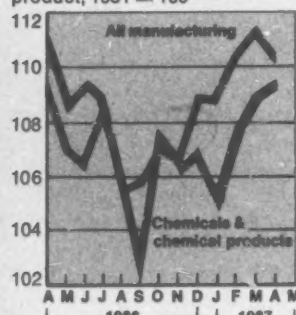
The 23 largest companies in the industry supply roughly two thirds of the fragrance and flavor composition market, but only one third of all essential oils and aroma chemicals. The remaining essential oils are supplied by small companies and brokers.

The aroma chemicals business, on the other hand, is increasingly like any other chemical business, with commodity items and specialty products. Most aroma chemicals are still supplied by flavors and fragrances companies, both large and small. But a significant proportion, one third, of the business has been snatched away by the big chemical producers, such as Rhône-Poulenc (with the vanillin operations of Monsanto) and BASF.

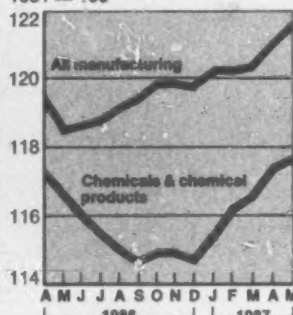
The worldwide market for flavors and fragrances will continue its modest growth, probably 3 to 5% per year, in constant dollars, the SRI report predicts. Nevertheless Daeniker concedes, some in the industry are worried about such nagging questions as whether "everything should be flavored." However, he says, "There is a true justification for fragrances and flavors. Not that they are necessary—first come the basic necessities, then come the nice things in life. And for that, fragrances and flavors are essential. They are almost so important for the quality of life that they are an essential. You can survive without them—but it's no fun!" □

Fertilizer dulls bright Canadian chemicals performance

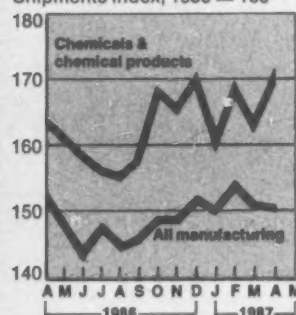
Volume index, gross domestic product, 1981 = 100



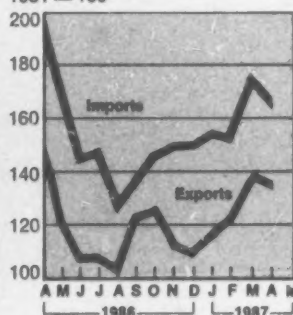
Industry selling price index, 1981 = 100



Shipments index, 1980 = 100



Chemical trade index, 1981 = 100



Note: 1981 = 100. Source: Statistics Canada

Fertilizer chemicals are hurting most

Production, thousands of metric tons	1986	1987	1988	% change 1986-87
ORGANICS				
Ethylene	1909	706	655	7.8%
Propylene	628	210	214	-1.9
Benzene	635	257	212	21.2
Toluene	393	142	120	18.3
Xylene	356	116	119	-2.5
PLASTICS				
Polyethylene, low density	987	318	282	12.8
Polyethylene, high density	242	86	80	7.5
Polyesters, unsaturated	37	15	12	25.0
INORGANICS				
Hydrochloric acid	153	53	54	-1.9
Nitric acid	1024	363	394	-7.9
Phosphoric acid*	547	180	239	-24.7
Sulfuric acid	3536	1313	1390	-5.5
Ammonia, anhydrous	3540	1202	1310	-5.5
Ammonium phosphate	1149	378	498	-24.1
Chlorine	1536	549	490	12.0
Sodium hydroxide	1696	600	532	12.8

* 100% P₂O₅. Source: Statistics Canada

For the Canadian chemical industry, the year so far has been very good—or very poor. It all depends upon what segment of the industry is being talked about. In petrochemicals, ethylene output continues to set new records, as derivative products such as polyethylene continue to score hefty gains.

This year, the Canadian pulp and paper industry is staging a strong recovery. This, in turn, has spurred domestic demand for pulping, bleaching, and paper-making chemicals.

But fertilizer producers, and the companies that make the chemicals that go into fertilizers, haven't been so lucky. Like most of their counterparts in other countries, worldwide overcapacity and a world grain surplus are taking their toll on the Canadian fertilizer industry.

Ethylene production, up almost 8% through the first four months of this year, is drawing its strength from a charged-up Canadian plastics industry, which almost certainly will chalk up another record year in 1987. In fact, the plastics and resins industry has been among the fastest-growing industries in Canada for the past several years. Based on four-month data, the latest available from Statistics Canada, low-density polyethylene output is running 13% ahead of last year's pace. Production of its cousin, high-density polyethylene, is up 7.5%.

Statistics Canada no longer publishes production data for polyvinyl chloride or polystyrene. But all signs indicate that demand for these two ethylene-consuming polymers also is growing. Demand for polystyrene in packaging is particularly heavy. As a result, supply of both polystyrene and styrene is tight in Canada. Prices of both the polymer and monomer have increased rapidly so far this year.

PVC producers are benefiting from a strong housing and construction market in Canada. But they have to share some of their good fortune with imported material. On the other hand, polyethylene producers are enjoying a strong export market. They now export about half of their output, most of it linear low-density polyethylene.

On the inorganics side, a 12% increase in four-month chlorine production reflects not only higher PVC output but a booming Canadian pulp and paper industry. Pulp and paper mills have boosted shipments and pared down inventories. Operating rates in the industry are close to 100%.

However, Canadian fertilizer producers are hurting. Markets remain weak for most of their major products. Prices are also weak and, although some new plants have started up, the situation has forced producers to shut down other units.

The statistics make dismal reading. Ammonia output, down 5.5% in the first four months. Ammonium phosphate, down 24% in the same period. Phosphoric acid, down 25%. Urea production is barely holding its own.

Earl Anderson, New York

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Facts & Figures for
**Chemical
R&D**
Page 32

News of the Week

■ **International Trade Commission** once again weighs dropping synthetic organic chemicals report, concerned by its cost, in time and money. **Page 4**

■ **NASA** considers several options in establishing long-range goals for its space program. **Page 5**

■ **Second-quarter 1987 chemical earnings** are generally up; pattern of gains is mixed. **Page 5**

■ **Opponents and proponents of acid rain control measures** have found several areas of agreement that may resolve Congressional impasse on this issue. **Page 6**

■ **Trade and competitiveness bill** is passed by the Senate, with a number of provisions important to the chemical industry. **Page 6**

Cover: Merck researcher devises process for producing potential new drug

Letters 2

Concentrates

Business 7

Government 15

Science/Technology 24

The Departments

New Products 65

ACS Comment 66

People 73

Newsclips 88

Business

Arco Chemical Europe aims to stress quality as it expands in specialty markets based on propylene oxide and *tert*-butyl alcohol. **Page 13**

Fledgling biotechnology company Cyanotech readies its first microalgae product for the market—powdered, free-flowing β -carotene. **Page 14**

Government

International group of chemical industry experts advises diplomats on technical problems of complying with chemical weapons treaty. **Page 16**

National Technical Information Service privatization proposal draws criticism from House subcommittee. **Page 21**

Technology

New measurement-related research and services are needed to deal with new technologies, says NBS report. **Page 28**

Series of low-cost supercomputing workstations that have up to 10 times the power of superminicomputers has been introduced. **Page 29**

New advanced scanners for gel electrophoresis will allow high-speed analysis for wide range of projects. **Page 30**

ACS News

Council will face two petitions—on "other committees" and resolution of election disputes—at its meeting in New Orleans. **Page 68**



Special Report

C&EN's annual compilation of data on research and development reveals that U.S. chemical R&D is growing modestly, with total expenditures expected to top \$122 billion in 1987. **Page 32**

House panel criticizes privatization of NTIS

David J. Hanson, C&EN Washington

The National Technical Information Service will not be run by a private contractor anytime soon if Congress has any say over it. However, U.S. science and technology information policy needs a major face-lift. Thus concluded the House Subcommittee on Science, Research & Technology after two-day hearings.

The hearings focused on two issues—general organization and distribution of information in the broad sense, and the proposed privatization of the National Technical Information Service.

Finding new and better mechanisms for getting scientific and technical information into the hands of people who can use it is being viewed as a partial solution to the U.S.'s economic competitiveness problems. Within the executive branch, the drive for better information policies comes from an April 10 Presidential executive order. That order, No. 12591, in part directs the National Science Foundation, the State Department, and the Commerce Department to develop "a central mechanism for the prompt and efficient dissemination of science and technology information developed abroad to users in federal laboratories, academic institutions, and the private sector on a fee-for-service basis."

But this is not the only movement under way to improve federal information services. Rep. George E. Brown Jr. (D.-Calif.) has introduced H.R. 1615, which would create a comprehensive Government Information Agency to oversee all federal information activities. The Department of Energy has begun a program of its own to improve information flow among its laboratories and researchers. And several agencies are trying to increase their access to foreign information, particularly from Japan.

The greatest attention, however, has been given to Administration efforts to turn NTIS over to the private sector. NTIS is not now a big office in the federal bureaucracy. It employs just 335 people and has a fiscal 1988 budget of about \$36 million. It was established 42 years ago as a government clearinghouse for the collection and distribution of information. It also collects reports from Western European nations and has additional duties under the 1986 Japanese Technical Literature Act.

By all accounts, it has performed its functions well. In 1986 NTIS distributed about 20,000 information items to customers every day. It is seen as a major and reliable source for private industry and researchers of technical information and reports generated by federal agencies. This function is entirely self-supporting and generated about \$22 million last year.

But a major tenet of the Reagan Administration is that the government is not in business to do business. The rationale is that private-sector companies can provide the same services at less cost than can the government. So agencies that sell government-generated products are targets for privatization. NTIS has been under the gun for some time, the idea first having come up in 1981. Last year the Commerce Department asked for public comments on privatization of NTIS, and many librarians and researchers responded that they did not think it was a good idea.

Proponents of the idea, almost entirely from within the Administra-



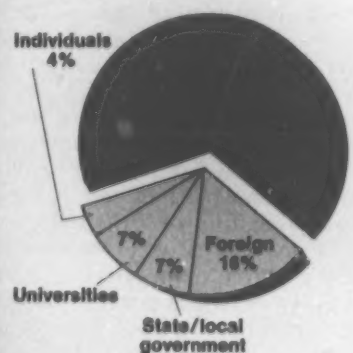
Walgren: NTIS has a library function

tion, claim that NTIS has been losing revenue of late because it has had to charge higher prices and because sales have been lower. So this year, the President's fiscal 1988 budget proposed that the private sector be given an opportunity to operate NTIS, with the government retaining overall control of policy.

Commerce is exploring two methods for privatizing NTIS. The first is to have an outside contractor operate NTIS. The contractor would keep most of the revenue generated from selling federal information and would return to the government only enough to pay for agencies' turning over documents to NTIS. More than 30 potential bidders for NTIS met with Commerce officials June 16 to get more information.

The second idea, also described at the June meeting, is a plan called Federal Employees Direct Corporate Ownership Opportunity Plan, or FED COOP. The FED COOP idea is currently favored by the Administration. According to David S. Nathan, Commerce's deputy assistant secretary for special projects, it would have the contractor offer jobs to current NTIS employees and would offer employees stock in the new firm created by the contractor. Six-month employment would be guaranteed current workers. For the

Industry is the largest user of NTIS services



1986 total revenue = \$22.4 million

Source: Department of Commerce



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Government

Administration, one attraction of this plan is that no legislation is believed needed to carry it out. It could be done under the Office of Management & Budget Circular A-76, which is used for other federal contracting to private industry.

But many users of NTIS are concerned that privatization would cause major problems. Rep. Doug Walgren (D.-Pa.), chairman of the science subcommittee, has introduced a bill, H.R. 2159, that would convert NTIS into a government corporation. Walgren also inserted into the National Bureau of Standards fiscal 1988 authorization bill, H.R. 2160, an amendment that would prohibit NTIS from contracting out any more of its work than it already has. It would also prevent any transfer of NTIS out of the federal government without legislation.

"NTIS is essentially a library function," Walgren says. "There is a reason why most of the libraries in this nation are charitable and not for profit, and that is because if the profit motive decides what is to be done in the library function, you will have improper emphasis given to certain kinds of information that may not presently be appreciated in the marketplace, but may be literally critical to be accessed by various users of information."

Members of the information industry, however, are concerned about the formation of a government corporation. They view it as potential competition to their own activities. James V. Seals, director of marketing and corporate development for the American Chemical Society's Chemical Abstracts Service, told the subcommittee that the definition used for "government information" could be stretched to include scientific research performed with federal funds. If a government information agency were to start distributing the results of such research, it would compete directly with private information services such as CAS. He also thinks the government corporation would duplicate other private-sector services, citing the development of the STN International database collection, which includes direct on-line scientific information from Western Europe and soon from Japan.



Brown: federal information neglected

Other speakers at the hearings had different objections to the privatization of NTIS. Kenneth B. Allen, vice president of government relations for the Information Industry Association, told the subcommittee that any contractor that took over NTIS would be running a big risk. It would not be able to protect its holdings by copyright and might not receive many of the government documents now going to NTIS. The result would be a gradual erosion of NTIS files.

John Shattuck, vice president for government, community, and public affairs for Harvard University, voiced similar reservations about NTIS privatization. Speaking on behalf of the Association of American Universities and the Association of Research Libraries, he said there is considerable fear in the research community that such a move would mean the loss of foreign research reports, increased prices for documents, commercially driven decisions about collections and services, and increasing pressure to delete sensitive but unclassified technical information from the NTIS database.

The one alternative to the present NTIS program that seemed to grab the subcommittee's interest was the suggestion from Ralph E. Kinnickell Jr., public printer of the U.S., that NTIS be transferred to the Government Printing Office. As head of GPO, Kinnickell says he has im-

proved the marketing strategy for government publications and has been able to return a "sizable surplus" to the Treasury. Kinnickell says the Superintendent of Documents Office at GPO already is doing much of what H.R. 1615 wants in the way of providing government information to the public. "The combination of GPO's size and NTIS's specialized skills can lead only to a more informed public," he concluded. Because GPO is under control of Congress and not the White House, as is the Department of Commerce, Congressmen seemed especially intrigued by the possibility of this kind of switch.

Despite the flurry of attention given NTIS, it is only one of hundreds of offices and agencies that distribute government information. The lack of any coordination among these is a main reason for Brown's attempt to set up a governmentwide office in H.R. 1615. "Federal information has not been properly managed," Brown says. "It has been neglected and overlooked to the extent that many members of both the Administration and Congress have suddenly realized that federal information is vital not only to our defense but to our economy and health." Although witnesses at the hearings related anecdotes about data collection through foreign service science officers of the State Department and of efforts to coordinate data among other agencies, it was clear there was little governmentwide cooperation.

Brown and Walgren were not convinced by arguments from the Administration that NTIS needs to be privatized. They see the federal role in distributing information as a service crucial to U.S. economic health. It is possible that private information services, such as STN International, will be able to do the job of organizing the vast amount of available government scientific and technical information better than the type of federal agency proposed in H.R. 1615, but that remains to be seen. Regardless of how information may be coordinated in the future, Congress and those that use the information are determined to keep NTIS part of the government for now. □

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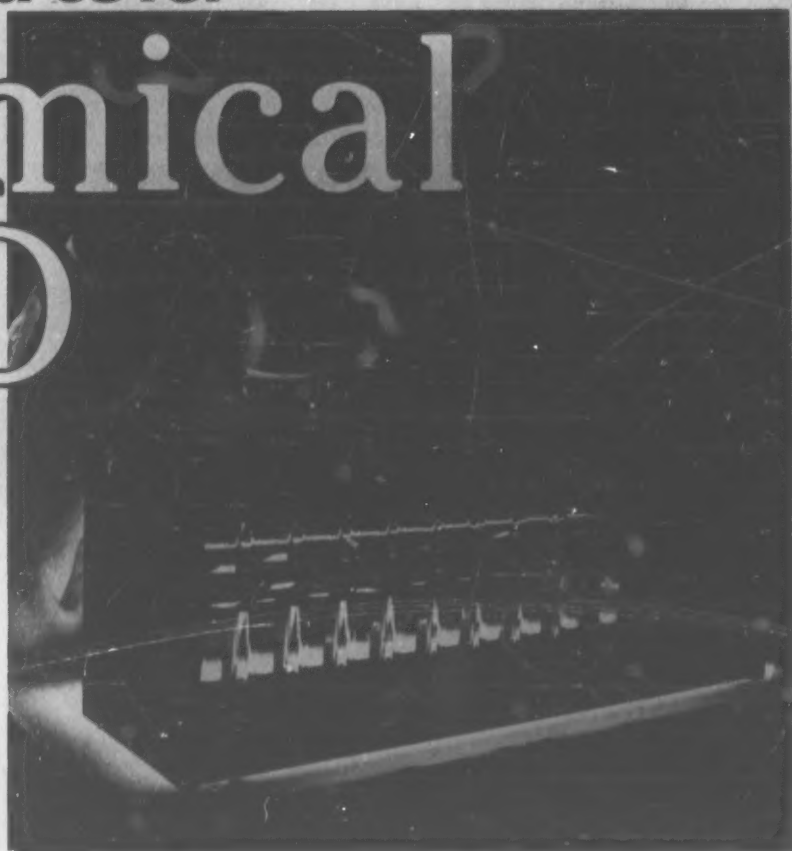
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Facts & Figures for Chemical R&D



Rebecca L. Rawls, C&EN Washington

Research and development in the U.S. is growing modestly. Total expenditures for R&D are expected to top \$122 billion in 1987, an increase of 6% over R&D spending from all sources last year. That's the smallest year-to-year change in the past decade, a decade that has seen R&D funding nearly triple, in current dollars, from 1977's \$42.8 billion. For the decade as a whole, R&D spending in the U.S. has been growing 11% per year—nearly twice the rate at which it is growing now.

Still, although significantly more modest than in the recent past, the increase in R&D funding expected this year does represent real growth, outpacing anticipated inflation by some 2%. In keeping with the recent pattern, about half that money comes from the federal government—\$60 billion in 1987—and almost all the rest from industry. Universities and other nonprofit institutions will kick in a relatively modest \$4.2 billion, only 3% of the total, this year.

Government spending for R&D is actually growing a good deal

1 Overview

A look at the total U.S. R&D effort. Where funds come from, who spends them, and how they are divided among basic and applied research and development. Who gets U.S. patents 35

2 Federal Government

R&D funding by the U.S. government. How much federal agencies spend and what they spend it on, especially for research in chemistry, physical sciences, and engineering..... 40

3 Industry

Spending for R&D by industry as a whole and by the chemical industry. How company size affects R&D spending. How much major companies spend on R&D. Employment trends in industrial R&D..... 51

4 Universities & Colleges

Where academic institutions get R&D funds and how they spend them. Which schools spend the most on all R&D and on chemistry. Degrees awarded in chemistry and chemical engineering..... 58



ETHY photo

faster than federal spending as a whole. If Gramm-Rudman deficit reduction targets are to be met in this year's budget—an event that most observers consider unlikely—the overall federal budget probably will rise only a very modest 1% for the year ending Sept. 30. Federal R&D support, by contrast, is expected to be up 7% for 1987 as a whole. In general, the Reagan Administration and Congress have been relatively kind to R&D budgets during the past seven years, doubling federal support for R&D from its pre-Reagan level of \$29.5 billion in 1980. Even when inflation is taken into account, federal R&D support has grown 46% since 1980.

Until recently, industrial support for R&D has kept pace with the federal effort. In 1986 and again in 1987, however, preliminary figures indicate that industry's support for R&D is lagging behind that of government. R&D spending by all industry is expected to rise 5% this year, following a 6% increase in 1986 and one of 7% in 1985. Federal support over the same period rose, on average, 10% per year.

Considered in a broader context,

however, current levels of support for R&D in the U.S. are quite high. R&D spending appears to be leveling off at about 2.7% of gross national product. For most of the past two decades it has been considerably lower than that, reaching its most recent nadir in 1978 at just above 2.1%. Not since the mid-1960s, when massive efforts in space and defense led the federal government to spend twice what industry did to support R&D, has such a large fraction of the nation's total output of goods and services, as measured by GNP, been devoted to supporting R&D. Though the rate of growth may be declining, overall support for R&D in the U.S. appears strong.

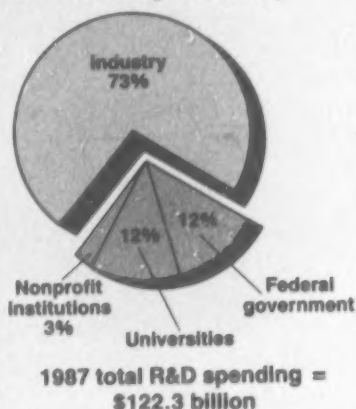
Chemical R&D, of course, is only a small piece of the total R&D picture. Just how much of the total national effort focuses on chemistry is never easy to measure, in part because the point where chemical R&D breaks off and R&D begins in some closely related field—materials science, say, or biotechnology—has never been clearly defined.

This year, separating out that part of the overall R&D effort that can reasonably be called chemical is

even harder than usual. That's because some of the key data, particularly on the industrially financed half of the R&D picture, have yet to be compiled by the National Science Foundation. NSF is the chief source of statistical information on R&D in the U.S., and its data—collected in large part by the Census Bureau—form much of the basis of this special report. Recent reorganizations at both the Census Bureau and NSF's division of science resources studies have delayed the compilation of some of these data by three or four months. As a result, the most recent data available for many aspects of industrial R&D spending are based on information collected in 1983, too long ago to give a precise picture of the state of that R&D effort now.

Of the federally funded half of U.S. R&D, the biggest share—69% for the 1987 fiscal year—is funded by the Defense Department. Defense's share of the federal R&D budget has been climbing steadily in recent years, from a level of about 45% that prevailed throughout the late 1970s. That shift parallels another one that is taking place, name-

Almost three quarters of all R&D is by industry



ly that more and more federal funds are going into the development part of R&D—72% in 1987, up from 64% five years ago. The Defense Department is the overwhelming source of federal development funds, supplying almost 90% in 1987.

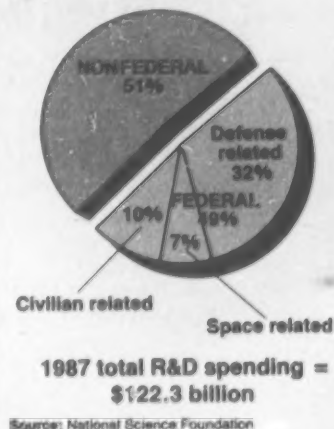
Chemical research also finds its single largest federal patron in the Defense Department, which in the 1987 budget year is expected to spend \$185 million for it. That's 28% of total federal chemical research support, which is estimated to reach \$671 million. Defense Department support is up 10% from 1986 levels. Growing even faster is support from the National Science Foundation, which expects a 17% boost in its funding for chemical research in fiscal 1987. That would bring its

support to \$132 million, nearly to the level of the second largest supporter of chemical research in the federal government—the Department of Energy, which expects to spend \$139 million on such research in fiscal 1987, down 6% from 1986. In fact, except for the Defense Department and NSF, all the major supporters of chemical research in the federal government will decrease their spending in this area in 1987. The net effect is a 3% rise overall for federal support for chemical research—no change at all when inflation is taken into account.

At universities, where half of the nation's basic research is performed, overall budgets for basic research were up a healthy 8% in 1986. Funds for applied R&D, which together account for only a third of total R&D spending at universities, also were up 8% in 1986. Spending at universities on chemical R&D reached \$450 million in 1986, also an 8% hike from 1985. The federal government is the principal funder of university R&D—supplying nearly two thirds of the \$11.1 billion universities expect to spend on R&D in 1987.

Though universities have a major role in performing basic research in the U.S., they trail far behind industry when it comes to carrying out applied research or development. In fact, industry will do 73% of the total R&D conducted in the U.S. this year, a fraction that has held essentially constant for the past decade. Universities and govern-

Federal funds account for half of all U.S. R&D



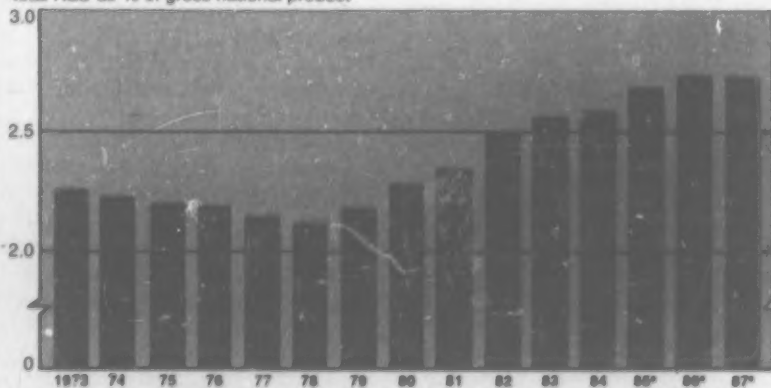
ment-run R&D facilities each perform about equal shares of the remainder.

Historically, the overall chemicals and allied products industry performs about 70% of all the applied R&D done on chemicals or drugs by industry. R&D performed by companies in the chemicals and allied products industry is estimated to have increased 10% in 1986 to \$9.5 billion. That level of growth is off a bit from the 12% average annual rate of increase for the past decade. When adjusted for inflation, however, the real growth in spending for 1986, at 7%, is slightly better than the 6% annual rate for the decade as a whole.

Growth in R&D at major industrial chemical companies was not so high as that for the chemicals and allied products industry as a whole in 1986—up only 4%. Some of this difference comes about because drug companies, which are part of the chemicals and allied products industry, are increasing their R&D spending faster than are basic chemical companies. Another contributing factor in a major divestment that took place at Union Carbide in 1986. The company sold off nearly \$2 billion of its assets, largely in consumer products fields. The much smaller Union Carbide spent less on R&D in 1986 than its predecessor company had in 1985. When this change is taken into account, major chemical company R&D spending rose 7% in 1986.

R&D share of U.S. GNP levels off after rise of early 1980s

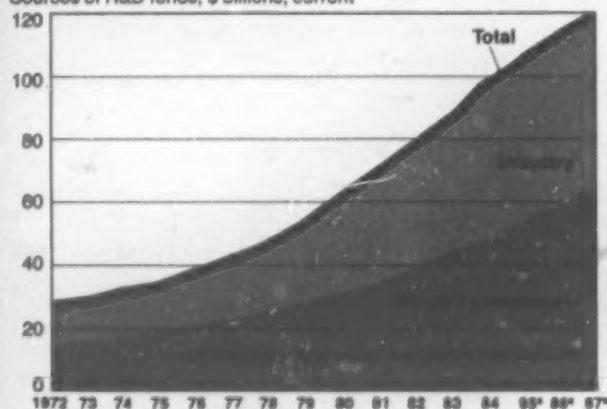
Total R&D as % of gross national product



R&D • Overview

Although U.S. outlays for R&D are up fourfold in the past 15 years . . .

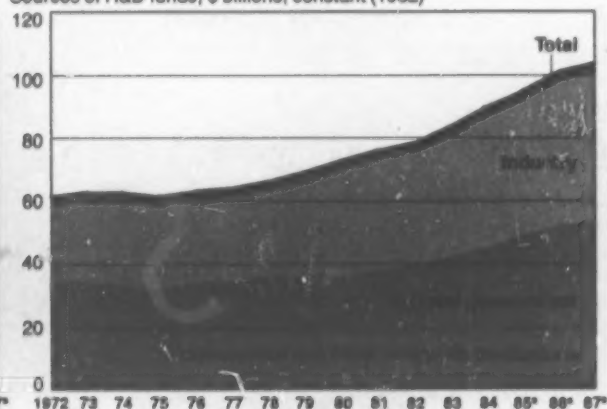
Sources of R&D funds, \$ billions, current



■ C&EN estimates. Source: National Science Foundation

. . . they are only two thirds higher if inflation is taken into account

Sources of R&D funds, \$ billions, constant (1982)



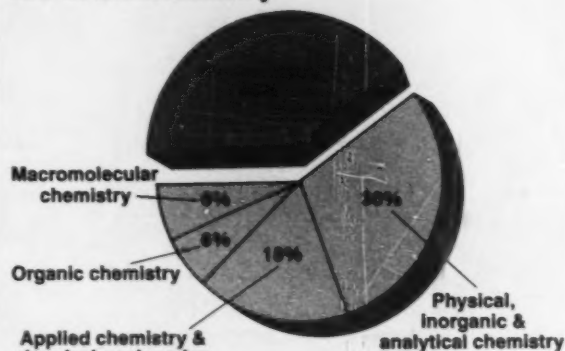
SOURCES OF R&D FUNDS: Industry and federal government each contribute nearly half

	\$ Billions (current)											Annual change	
	1987*	1986*	1985*	1984	1983	1982	1981	1980	1979	1978	1977	1986-87	1977-87
Industry	\$ 58.1	\$ 55.3	\$ 52.2	\$48.8	\$43.5	\$40.1	\$35.9	\$30.9	\$26.1	\$22.5	\$19.6	5%	11%
Federal government	60.0	56.0	51.8	45.6	40.7	36.5	33.4	29.5	26.8	23.9	21.6	7	11
Universities and colleges	2.7	2.5	2.3	2.0	1.9	1.7	1.5	1.3	1.2	1.0	0.9	8	12
Other nonprofit institutions	1.5	1.4	1.3	1.2	1.1	1.0	1.0	0.9	0.8	0.8	0.7	7	8
TOTAL	\$122.3	\$115.2	\$107.5	\$97.6	\$87.2	\$79.3	\$71.8	\$62.6	\$54.9	\$48.1	\$42.8	6%	11%
ANNUAL CHANGE	6%	7%	10%	12%	10%	10%	15%	14%	14%	12%	10%		

	\$ Billions (1982, constant)											Annual change	
	1987*	1986*	1985*	1984	1983	1982	1981	1980	1979	1978	1977	1986-87	1977-87
Industry	\$ 48.8	\$ 48.3	\$46.8	\$45.2	\$41.9	\$40.1	\$38.3	\$36.1	\$33.2	\$31.1	\$28.2	1%	5%
Federal government	50.4	48.9	46.5	42.3	39.2	36.5	35.7	34.5	34.3	33.2	30.8	3	5
Universities and colleges	2.3	2.2	2.1	1.9	1.8	1.7	1.6	1.6	1.5	1.4	1.3	5	6
Other nonprofit institutions	1.3	1.2	1.2	1.1	1.1	1.0	1.0	1.1	1.1	1.1	1.0	8	3
TOTAL	\$102.7	\$100.6	\$96.4	\$90.5	\$83.9	\$79.3	\$76.6	\$73.2	\$70.1	\$66.8	\$63.7	2%	5%
ANNUAL CHANGE	2%	4%	7%	8%	6%	4%	5%	4%	5%	5%	2%		

■ C&EN estimates. Source: National Science Foundation

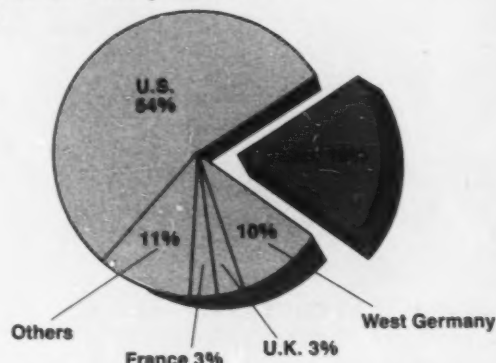
Two fifths of chemistry papers are in biochemistry



1986 total papers^a = 474,429

^a Number of abstracts of papers published in Chemical Abstracts.
Source: Chemical Abstracts Service

Japanese now receive nearly 20% of U.S. patents



1986 total U.S. patents issued = 70,860

Source: U.S. Patent & Trademark Office

PERFORMERS OF R&D: Industry's share is six times that of government

	\$ Billions (current)											Annual change	
	1987 ^a	1986 ^a	1985 ^a	1984	1983	1982	1981	1980	1979	1978	1977	1986-87	1977-87
Industry	\$ 88.7	\$ 84.4	\$ 78.2	\$ 71.5	\$ 63.4	\$ 58.0	\$ 51.8	\$ 44.5	\$ 38.2	\$ 33.3	\$ 29.8	5%	12%
Federal government	15.1	13.4	13.0	11.6	10.6	9.1	8.4	7.6	7.4	6.8	6.0	13	10
Universities and colleges	10.7	10.3	9.5	8.5	7.8	7.3	6.8	6.1	5.4	4.6	4.1	4	10
University-associated FFRDCs ^b	4.0	3.8	3.5	3.1	2.7	2.5	2.5	2.2	1.9	1.7	1.4	5	11
Other nonprofit institutions	3.7	3.4	3.3	3.0	2.7	2.4	2.3	2.2	2.0	1.7	1.5	9	9
TOTAL	\$122.3	\$115.2	\$107.5	\$97.6	\$87.2	\$79.3	\$71.8	\$62.6	\$54.9	\$46.1	\$42.8	6%	11%

\$ Billions (1982, constant)

	1987 ^a	1986 ^a	1985 ^a	1984	1983	1982	1981	1980	1979	1978	1977	1986-87	1977-87
Industry	\$ 74.5	\$ 73.7	\$ 70.1	\$ 66.9	\$ 61.0	\$ 58.0	\$ 55.1	\$ 51.9	\$ 48.7	\$ 46.1	\$ 44.3	1%	5%
Federal government	12.7	11.7	11.7	10.8	10.2	9.1	9.0	9.0	9.5	9.5	9.0	9	4
Universities and colleges	9.0	9.0	8.5	7.9	7.5	7.3	7.3	7.2	6.9	6.4	6.1	6	4
University-associated FFRDCs ^b	3.4	3.3	3.1	2.9	2.6	2.5	2.7	2.7	2.5	2.4	2.1	3	5
Other nonprofit institutions	3.1	3.0	3.0	2.8	2.6	2.4	2.4	2.5	2.5	2.3	2.2	3	3
TOTAL	\$102.7	\$100.6	\$96.4	\$90.5	\$83.9	\$79.3	\$76.6	\$73.2	\$70.1	\$66.8	\$63.7	2%	5%

^a C&EN estimates. ^b Federally funded R&D centers. Those administered by both industry and by nonprofit institutions are included in totals for their respective sectors.
Source: National Science Foundation

CHARACTER OF R&D: Uniform growth in all three sectors

	\$ Billions (current)											Annual change	
	1987 ^a	1986 ^a	1985 ^a	1984	1983	1982	1981	1980	1979	1978	1977	1986-87	1977-87
Basic research	\$ 14.7	\$ 13.8	\$ 13.0	\$ 12.1	\$ 11.0	\$ 9.9	\$ 9.2	\$ 8.1	\$ 7.3	\$ 6.4	\$ 5.5	7%	10%
Applied research	26.4	24.7	23.4	22.3	20.4	18.5	16.9	14.1	12.3	10.8	9.7	7	11
Development	81.2	76.5	71.1	62.9	55.8	50.9	45.8	40.5	35.3	30.9	27.5	6	11
TOTAL	\$122.3	\$115.2	\$107.5	\$97.6	\$87.2	\$79.3	\$71.8	\$62.6	\$54.9	\$46.1	\$42.8	6%	11%

\$ Billions (1982, constant)

	1987 ^a	1986 ^a	1985 ^a	1984	1983	1982	1981	1980	1979	1978	1977	1986-87	1977-87
Basic research	\$ 12.3	\$ 12.1	\$ 11.7	\$ 11.2	\$ 10.6	\$ 9.9	\$ 9.8	\$ 9.5	\$ 9.3	\$ 8.9	\$ 8.3	2%	4%
Applied research	22.2	21.6	21.0	20.7	19.6	18.5	18.0	16.5	15.8	15.1	14.5	3	4
Development	68.2	66.8	63.8	58.3	53.7	50.9	48.8	47.3	45.0	42.8	40.9	2	5
TOTAL	\$102.7	\$100.6	\$96.4	\$90.5	\$83.9	\$79.3	\$76.6	\$73.2	\$70.1	\$66.8	\$63.7	2%	5%

^a C&EN estimates. Source: National Science Foundation

PATENT ACTIVITY OF U.S. COMPANIES:^a Significant decline for chemicals in 1986

Number of patents issued	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	Total 1977-86
CHEMICAL COMPANIES											
Dow Chemical	371	335	328	246	276	260	249	217	334	297	2,913
Du Pont	329	342	348	326	283	343	289	227	386	431	3,304
Ciba-Geigy	244	305	290	244	281	345	309	248	347	354	2,967
Union Carbide	208	242	231	182	202	262	211	197	215	224	2,174
PPG Industries	124	128	137	137	177	189	166	118	190	196	1,562
Monsanto	110	100	138	136	131	211	205	144	264	192	1,631
American Cyanamid	92	115	111	128	129	188	205	143	225	215	1,551
Olin	81	117	112	85	80	80	106	82	99	91	933
Ethyl	77	105	76	44	31	43	51	25	41	46	539
International Flavors & Fragrances	76	104	95	87	87	96	76	60	80	52	813
Stauffer Chemical	75	104	95	81	87	94	93	80	132	116	957
Celanese	66	67	94	57	56	58	56	44	71	70	639
Hercules	43	41	39	37	30	52	23	24	49	51	389
W. R. Grace	42	45	57	52	49	68	72	56	76	63	580
Rohm & Haas	33	31	37	55	49	77	74	77	95	94	622
GAF	12	23	19	21	32	47	48	54	57	26	339
TOTAL^b	1983	2204	2207	1918	1980	2413	2233	1796	2661	2518	21,913
ANNUAL CHANGE	-10%	0%	15%	-3%	-18%	8%	24%	-33%	6%	-9%	

^a Includes U.S. chemical companies or U.S.-based subsidiaries of foreign companies that have received more than 999 U.S. patents since 1962. ^b These totals include patents issued to the chemical companies shown in this table only. Source: U.S. Patent & Trademark Office

U.S. PATENTS: Those of foreign origin rose 2% in 1986 as those of U.S. origin declined 4%

Number of patents issued	1986	1985	1984	1983	1982	1981	1980	1979 ^a	1978	1977	Total 1977-86
U.S. origin	38,124	39,554	38,365	32,871	33,896	39,223	37,356	30,079	41,254	41,485	372,207
to U.S. corporations	27,324	28,944	28,002	24,038	24,085	27,623	25,967	21,145	29,421	29,566	266,115
to U.S. government	1,011	1,124	1,228	1,043	1,003	1,117	1,232	961	1,233	1,484	11,436
to individuals in the U.S.	9,461	9,243	8,887	7,562	8,539	10,241	9,940	7,804	10,399	10,249	92,325
to foreign-owned corporations in the U.S.	328	243	248	228	269	242	217	169	201	186	2,331
Foreign origin	32,736	32,107	28,835	23,989	23,992	26,548	24,463	18,775	24,848	23,784	260,077
to U.S.-owned corporations abroad	2,231	2,274	2,032	1,660	1,715	1,839	1,894	1,364	1,961	1,970	18,740
to foreign corporations	26,196	25,721	22,985	19,019	18,589	20,549	18,665	14,447	18,875	17,879	202,925
to foreign governments	471	483	440	336	368	249	253	186	249	215	3,250
to foreign individuals	3,838	3,629	3,378	2,974	3,320	3,911	3,851	2,778	3,763	3,720	35,162
TOTAL	70,860	71,661	67,200	56,860	57,888	65,771	61,819	48,854	66,102	65,269	632,284
% FOREIGN	46.2%	44.8%	42.9%	42.2%	41.4%	40.4%	39.6%	38.4%	37.6%	36.4%	41.1%

^a Patent figures were low in 1979 because the U.S. Patent & Trademark Office was short of funds to print patents it might otherwise have issued. Source: U.S. Patent & Trademark Office

HOLDERS OF U.S. PATENTS: Japan's share doubles in past decade

% of patents	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	Total 1977-86	1963-76
U.S. origin	54	55	57	58	59	60	60	62	62	64	59	73
Foreign origin^a	46	45	43	42	41	40	40	38	38	36	41	27
Japan	19	18	17	15	14	13	12	11	10	10	14	5
West Germany	10	9	9	10	9	10	9	9	9	8	9	7
U.K.	3	3	3	3	4	4	4	4	4	4	4	4
France	3	3	3	3	3	3	3	3	3	3	3	3
Switzerland	2	2	2	2	2	2	2	2	2	2	2	2
Canada	2	2	2	2	2	2	2	2	2	2	2	2
Sweden	1	1	1	1	1	1	1	1	1	1	1	1
Italy	1	1	1	1	1	1	1	1	1	1	1	1
Netherlands	1	1	1	1	1	1	1	1	1	1	1	1
U.S.S.R.	—	—	—	—	—	1	1	1	1	1	—	—
Others	2	—	—	—	—	—	—	—	—	—	3	2

^a Data for individual countries may not equal this number because of rounding. Source: U.S. Patent & Trademark Office

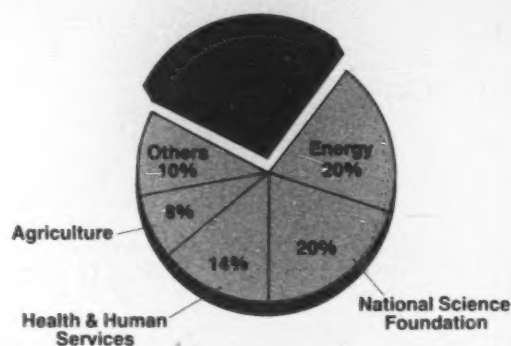
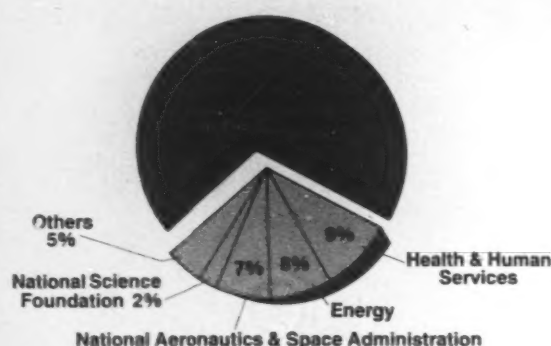
ABSTRACTS OF PAPERS IN *CHEMICAL ABSTRACTS*: Biochemistry's share holds steady at 40%

	1988	1985	1984	1983	1982	1981	1978	Percentage point change, 1978-88
BIOCHEMISTRY	40.4%	40.5%	40.5%	38.3%	39.5%	39.0%	38.8%	1.6%
% of all biochemistry abstracts								
Mammalian hormones ^a	12.5%	12.3%	12.4%	12.9%	12.2%	6.8%	5.9%	6.6%
Pharmacology	12.2	12.3	11.6	11.8	12.0	12.4	12.0	0.2
Mammalian biochemistry ^a	10.8	11.1	11.3	11.1	11.6	15.6	16.3	-5.5
Toxicology	7.8	7.9	8.0	8.5	8.1	8.7	6.4	1.4
Immunochemistry	6.1	5.3	4.8	4.2	4.4	3.4	—	—
Biochemical genetics ^b	6.1	5.2	4.2	3.8	3.3	—	—	—
Microbial biochemistry ^a	5.7	5.7	5.2	5.1	5.3	5.6	5.0	0.7
Enzymes	5.6	5.6	5.6	6.1	5.9	5.9	6.4	-0.8
Plant biochemistry ^a	5.2	5.5	6.2	5.9	6.2	5.8	6.1	-0.9
Biochemical methods	5.0	4.9	4.9	4.9	4.6	5.7	—	—
General biochemistry	4.7	4.9	5.3	5.8	6.0	7.5	7.1	-2.4
Others	18.3	19.3	20.3	19.9	20.4	22.6	34.8	—
PHYSICAL, INORGANIC, AND ANALYTICAL CHEMISTRY	29.8	29.8	28.8	29.6	28.5	28.0	27.5	2.3
% of all physical, inorganic, and analytical chemistry abstracts								
Spectra	20.0	18.4	18.0	17.6	17.2	18.0	17.8	2.2
Nuclear chemistry	19.9	21.8	22.2	22.5	22.6	21.6	19.7	0.2
Electric phenomena	10.8	10.8	10.8	10.0	10.5	11.0	10.5	0.3
Crystallography and liquid crystals	7.0	7.5	7.8	8.3	8.7	8.9	9.7	-2.7
General physical chemistry	7.0	6.9	6.9	7.3	7.3	7.2	7.0	0.0
Analytical chemistry	6.8	6.1	6.3	6.2	5.4	5.8	6.6	0.2
Others	28.5	28.5	28.0	28.1	28.3	27.5	28.7	-0.2
APPLIED CHEMISTRY AND CHEMICAL ENGINEERING	18.2	18.4	17.6	19.4	19.5	19.1	18.8	-0.6
% of all applied chemistry and chemical engineering abstracts								
Water, wastes, and pollution	21.9	20.2	21.0	19.6	21.7	24.0	18.6	3.3
Metals and alloys	20.8	20.0	18.9	19.1	22.2	17.9	27.8	-7.0
Mineralogical and geological chemistry	12.0	12.5	14.6	14.1	13.6	14.1	17.6	-5.6
Fossil fuels, derivatives, and related products	9.0	10.1	10.1	10.3	9.4	9.4	6.0	3.0
Unit operations and processes	7.1	7.5	7.0	7.5	6.9	6.4	4.6	2.3
Others	29.2	29.7	28.4	29.4	26.2	28.2	25.2	4.0
ORGANIC CHEMISTRY	5.9	6.4	7.6	7.3	7.2	8.7	8.7	-2.8
% of all organic chemistry abstracts								
Physical organic chemistry	27.3	30.6	32.0	30.5	31.5	37.0	38.4	-11.1
Organometallic and organometalloidal compounds	18.3	16.2	17.1	16.3	14.8	8.3	8.7	9.6
Heterocyclic compounds ^a	15.0	16.1	15.6	16.2	15.6	18.2	17.4	-2.4
Carbohydrates	7.8	5.7	5.7	5.8	5.8	5.4	5.1	2.7
Aromatic compounds ^a	7.3	6.3	6.3	7.1	7.2	8.7	8.0	-0.7
Biomolecules and their synthetic analogs ^b	5.0	4.9	4.4	4.5	3.7	—	—	—
Aliphatic compounds ^a	4.4	4.2	3.6	4.3	5.2	6.6	6.5	-2.1
Amino acids, peptides, and proteins ^a	3.9	4.6	4.8	4.5	4.4	4.2	4.3	-0.4
Others	11.0	11.4	10.5	10.8	11.8	11.6	11.6	—
MACROMOLECULAR CHEMISTRY	5.7	4.9	5.5	5.4	5.3	5.2	6.2	-0.5
% of all macromolecular chemistry abstracts								
Synthetic high polymers	34.1	34.1	34.0	34.4	34.7	30.3	28.3	5.8
Plastics manufacture and uses	23.8	25.3	24.2	24.4	21.9	26.4	26.8	-3.0
Cellulose, lignin, paper, and other wood products	9.8	9.1	9.6	9.1	9.7	10.1	9.1	0.7
Textiles	8.8	8.2	7.3	7.9	8.9	9.9	11.1	-2.3
Coatings, inks, and related products	7.2	7.2	7.8	6.6	7.6	7.5	7.6	-0.4
Synthetic elastomers and natural rubber	6.7	6.8	7.3	7.5	7.8	7.9	8.6	-1.9
Others	9.6	9.3	9.8	10.1	9.4	7.9	8.5	1.1

How to read this table: Using biochemistry as an example, 40.4% of all the papers abstracted by Chemical Abstracts Service in 1988 are in the various subdisciplines of biochemistry; 12.5% of all abstracts in biochemistry, in turn, are in the subdiscipline of mammalian hormones, 12.2% of biochemistry abstracts are in pharmacology, and so on. ^a Definition of section changed in 1982. ^b New section in 1982. Source: Chemical Abstracts Service

Defense's share of federal support grows

Defense gets nearly 70% of federal R&D funding but less than a third of funds for chemistry



Source: National Science Foundation

FEDERAL OBLIGATIONS FOR R&D: Up strongly thanks to big boost for military funds

\$ Millions	1987*	1986*	1985	1984	1983	1982	Annual change	
							1986-87	1982-87
Defense	\$40,678.8	\$33,646.3	\$29,791.5	\$25,372.9	\$22,992.8	\$20,622.6	21%	15%
Air Force	17,356.5	13,757.5	13,260.9	12,091.6	10,812.6	9,357.9	26	13
Navy	10,700.8	10,137.3	9,127.4	7,605.6	6,068.2	5,845.1	6	13
Army	5,710.2	4,850.2	4,570.8	4,225.5	3,998.1	3,760.5	18	9
Defense agencies ^b	6,775.3	4,790.7	2,781.7	1,391.5	2,052.3	1,618.1	41	33
Health & Human Services	5,270.8	5,611.3	5,451.0	4,830.7	4,352.5	3,940.7	-6	6
National Institutes of Health	4,672.3	4,977.3	4,827.7 ^a	4,257.4	3,789.2	3,433.1	-6	3
Alcohol, Drug Abuse & Mental Health Administration	383.1	396.2	377.6	337.2	302.2	248.1	-3	9
Energy	4,770.7	4,691.6	4,996.0	4,673.6	4,536.7	4,708.2	2	0
National Aeronautics & Space Administration	3,926.0	3,478.4	3,327.2	2,821.9	2,661.6	3,077.9	13	5
National Science Foundation	1,508.3	1,333.5	1,345.6	1,202.8	1,062.0	975.3	13	9
Agriculture	909.2	923.0	943.0	866.2	847.6	797.3	-1	3
Agricultural Research Service	497.0	463.1	469.7	451.3	443.4	404.9	7	4
Cooperative State Research Service	234.4	263.1	284.3	235.7	232.3	219.0	-11	1
Forest Service	111.5	120.1	113.1	108.4	107.7	112.1	-7	0
Interior	350.6	388.3	391.7	410.9	382.5	381.1	-10	-2
Geological Survey	207.6	218.6	214.9	208.9	157.0	152.6	-5	6
Environmental Protection Agency	309.6	333.6	320.4	261.2	240.7	335.1	-7	-2
Commerce	300.9	391.1	398.8	358.2	335.0	336.3	-23	-2
National Oceanic & Atmospheric Administration	196.3	268.1	269.8	244.3	222.0	222.0	-27	-2
National Bureau of Standards	91.4	99.3	100.5	95.5	95.0	88.8	-8	1
Others	1,184.7	1,264.7	1,367.1	1,426.5	1,300.1	1,258.1	-6	-1
TOTAL	\$59,209.6	\$52,061.8	\$48,332.3	\$42,224.9	\$38,711.5	\$36,432.6	14%	10%
ANNUAL CHANGE	14%	8%	14%	9%	6%	4%		

Note: Fiscal years. a Estimated. b Includes Defense Advanced Research Projects Agency, Defense Nuclear Agency, and others. Source: National Science Foundation

PERFORMERS OF FEDERALLY FUNDED RESEARCH: 54% is undertaken by industry

\$ Millions	1987 ^a	1986 ^a	1985	1984	1983	1982	Annual change	
							1986-87	1982-87
Industry	\$31,787.9	\$26,847.9	\$23,774.3	\$20,361.5	\$18,649.0	\$18,698.6	18%	11%
Federal intramural programs	15,396.7	13,533.4	12,998.4	11,572.3	10,581.9	9,141.0	14	11
Universities and colleges	6,558.7	6,554.7	6,299.0	5,565.1	4,966.4	4,605.5	0	7
University-associated FFRDCs^b	2,712.8	2,446.2	2,534.5	2,324.9	2,265.8	1,976.7	11	7
Nonprofit institutions	2,451.3	2,318.1	2,365.0	2,094.4	1,822.9	1,612.3	6	9
Foreign	219.8	257.8	255.9	175.8	239.5	214.3	-15	1
State and local governments	82.4	103.6	105.2	130.9	186.0	184.3	-20	-15
TOTAL	\$59,209.8	\$52,061.8	\$48,332.3	\$42,224.9	\$38,711.5	\$36,432.6	14%	10%

Note: Fiscal years. a Estimated. b Federally funded R&D centers. Those administered by both industry and by nonprofit institutions are included in totals for their respective sectors. Source: National Science Foundation

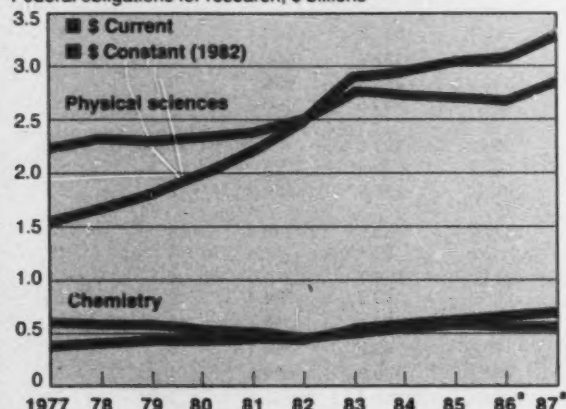
FEDERAL OBLIGATIONS FOR SCIENTIFIC DISCIPLINES: Slow growth for chemistry this year

\$ Millions for research only	1987 ^a	1986 ^a	1985	1984	1983	1982	Annual change	
							1986-87	1982-1987
Life sciences	\$ 6,289.2	\$ 6,457.6	\$ 6,366.2	\$ 5,635.9	\$ 5,177.9	\$ 4,745.5	-3%	6%
Engineering	3,857.8	3,684.4	3,628.5	3,624.1	3,517.0	3,386.5	5	3
Chemical	186.0	243.5	254.1	144.5	145.0	95.1	-24	14
Metallurgy and materials	465.5	464.1	439.1	341.1	332.5	309.1	0	9
Physical sciences	3,300.3	3,071.8	3,044.0	2,969.0	2,891.4	2,500.4	7	6
Chemistry	670.9	653.4	644.5	606.4	520.3	481.2	3	7
Physics	1,965.4	1,829.4	1,820.0	1,836.4	1,854.6	1,610.5	7	4
Environmental sciences	1,483.4	1,458.2	1,403.6	1,275.9	1,251.2	1,148.3	2	5
Mathematics and computer sciences	759.0	665.0	577.5	440.3	419.4	350.1	14	17
Other sciences	1,151.4	1,117.7	1,110.3	1,033.6	996.6	891.4	3	5
TOTAL	\$16,841.1	\$16,454.7	\$16,130.1	\$14,978.8	\$14,253.5	\$13,022.2	2%	5%
ANNUAL CHANGE	2%	2%	8%	5%	9%	7%		

a Estimated. Source: National Science Foundation

Federal support for physical science little changed since 1983 in real dollars

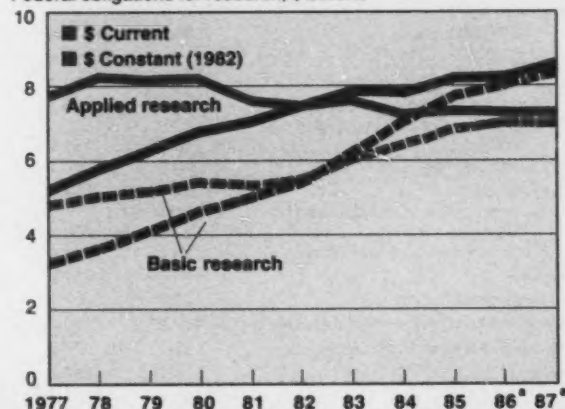
Federal obligations for research, \$ billions



Note: Fiscal years. a Estimated. Source: National Science Foundation

Government funding of basic research catching up with applied research support

Federal obligations for research, \$ billions



Note: Fiscal years. a Estimated. Source: National Science Foundation

FEDERAL OBLIGATIONS FOR BASIC RESEARCH: Little growth this year

\$ Millions	1987 ^a	1986 ^a	1985	1984	1983	1982	Annual change	
							1986-87	1982-1987
Health & Human Services	\$3162.4	\$3357.1	\$3232.5	\$2814.5	\$2475.4	\$2144.7	-8%	8%
National Institutes of Health	2938.3	3133.6	3018.0 ^a	2624.8	2313.0	2020.7	-6	8
Alcohol, Drug Abuse & Mental Health Administration	204.4	206.2	196.8	170.8	145.0	117.3	-1	12
National Science Foundation	1422.6	1255.7	1261.8	1132.3	999.1	916.1	13	9
Energy	1063.1	945.9	942.6	830.4	767.7	642.2	12	11
Defense	995.9	994.3	861.4	847.9	785.6	686.7	0	8
Navy	385.6	350.5	343.1	315.8	305.4	280.3	10	7
Air Force	284.5	234.4	198.3	192.4	164.2	145.8	21	14
Army	249.3	242.4	240.8	222.1	208.3	187.7	3	6
Defense agencies ^b	76.5	167.0	79.2	117.6	107.7	72.9	-54	1
National Aeronautics & Space Administration	986.1	850.4	750.9	754.5	617.0	535.7	16	13
Agriculture	434.1	432.7	445.4	392.6	362.0	330.8	0	6
Agricultural Research Service	267.2	247.6	250.2	240.6	215.3	192.9	8	7
Cooperative State Research Service	115.8	126.2	141.5	99.6	98.8	91.3	-8	5
Forest Service	43.1	50.5	44.1	41.2	38.8	38.7	-15	2
Interior	115.7	137.6	138.3	125.9	103.0	76.5	-16	9
Geological Survey	79.5	83.4	80.5	78.9	64.7	52.6	-3	9
Environmental Protection Agency	37.0	39.3	38.6	29.6	22.2	32.7	-6	3
Commerce	19.5	22.1	23.2	20.6	19.2	16.9	-12	3
National Bureau of Standards	19.1	21.2	22.1	20.2	18.4	16.5	-10	3
National Oceanic & Atmospheric Administration	0	0	0	0	0	0	-	-
Others	111.3	110.0	124.0	119.1	108.9	99.3	1	2
TOTAL	\$8347.7	\$8145.1	\$7818.7	\$7067.4	\$6260.1	\$5481.6	2%	9%
ANNUAL CHANGE	2%	4%	11%	13%	14%	9%		

Note: Fiscal years. a Estimated. b Includes Defense Advanced Projects Agency, Defense Nuclear Agency, and others. Source: National Science Foundation

FEDERAL OBLIGATIONS FOR APPLIED RESEARCH: Increases for Defense, NASA, and NSF

\$ Millions	1987 ^a	1986 ^a	1985	1984	1983	1982	Annual change	
							1986-87	1982-1987
Defense	\$2636.1	\$2364.8	\$2306.9	\$2200.7	\$2437.0	\$2266.1	11%	3%
Army	719.4	551.3	582.6	486.7	485.3	451.6	30	10
Air Force	562.2	573.4	538.4	547.7	524.2	488.1	-2	3
Navy	464.6	463.9	448.2	449.6	521.6	498.4	0	-1
Defense agencies ^b	889.9	776.2	737.7	716.6	905.9	828.1	15	1
Health & Human Services	1724.0	1834.0	1795.8	1651.5	1545.4	1480.9	-6	3
National Institutes of Health	1368.2	1452.8	1410.1 ^a	1285.6	1165.2	1103.8	-6	4
Alcohol, Drug Abuse & Mental Health Administration	177.5	188.8	179.7	165.2	155.4	128.7	-6	7
National Aeronautics & Space Administration	1396.5	1114.4	1032.7	954.7	927.8	871.4	25	10
Energy	913.3	1080.4	1198.4	1194.5	1193.4	1053.9	-15	-3
Agriculture	444.0	458.8	465.6	442.2	455.5	435.7	-3	0
Agricultural Research Service	202.4	188.1	191.8	183.7	202.6	186.2	8	2
Cooperative State Research Service	118.7	136.9	142.8	136.2	133.5	127.7	-13	-1
Forest Service	65.4	66.7	65.7	63.9	65.1	69.0	-2	-1
Commerce	236.7	304.4	301.0	276.1	285.6	259.2	-22	-2
National Oceanic & Atmospheric Administration	163.8	229.7	224.4	197.7	188.9	188.5	-29	-3
National Bureau of Standards	63.5	65.6	64.5	63.5	63.1	57.4	-3	2
Interior	210.9	227.5	231.0	254.3	254.7	275.0	-7	-5
Geological Survey	118.2	127.8	130.0	125.1	89.9	99.4	2	6
Environmental Protection Agency	170.0	180.4	176.0	142.3	152.4	210.7	-8	-4
National Science Foundation	85.7	77.8	83.8	70.5	62.9	57.1	10	8
Others	676.2	667.0	720.3	724.6	698.7	650.6	1	1
TOTAL	\$8493.4	\$8309.5	\$8311.5	\$7911.4	\$7993.4	\$7540.6	2%	2%
ANNUAL CHANGE	2%	0%	5%	-1%	6%	5%		

Note: Fiscal years. a Estimated. b Includes Defense Advanced Research Projects Agency, Defense Nuclear Agency, and others. Source: National Science Foundation

FEDERAL OBLIGATIONS FOR DEVELOPMENT: Nearly 90% goes for military work

\$ Millions	1987*	1988*	1985	1984	1983	1982	Annual change	
							1988-87	1982-87
Defense	\$37,046.8	\$30,287.2	\$26,623.2	\$22,324.3	\$19,770.1	\$17,869.8	22%	16%
Air Force	16,509.8	12,949.7	12,524.3	11,351.5	10,124.2	8,724.0	27	14
Navy	9,850.6	9,322.9	8,336.1	6,840.2	5,241.2	5,066.4	6	14
Army	4,741.6	4,056.6	3,747.4	3,516.8	3,304.5	3,121.3	17	9
Defense agencies ^b	5,808.9	3,847.5	1,964.8	557.3	1,038.7	717.1	51	52
Energy	2,794.4	2,665.3	2,825.0	2,648.7	2,575.8	3,012.1	5	-1
National Aeronautics & Space Administration	1,543.4	1,513.8	1,543.6	1,112.7	1,116.8	1,670.7	2	-2
Health & Human Services	384.3	420.2	422.7	364.7	331.7	335.2	-9	3
National Institutes of Health	365.8	390.9	399.6 ^a	347.0	311.0	308.7	-6	3
Alcohol, Drug Abuse & Mental Health Administration	1.2	1.2	1.1	1.2	1.8	2.1	0	-11
Environmental Protection Agency	102.6	113.9	105.8	89.2	66.1	91.7	-10	2
Commerce	44.7	64.6	74.6	61.5	50.2	80.2	-31	-6
National Oceanic & Atmospheric Administration	32.5	38.4	45.4	46.6	33.1	33.5	-15	-1
National Bureau of Standards	8.8	12.5	14.0	11.8	13.6	14.9	-30	-10
Agriculture	31.1	31.5	32.0	31.3	30.0	30.8	-1	0
Agricultural Research Service	27.4	27.4	27.7	27.0	25.5	25.8	0	1
Forest Service	3.0	2.9	3.3	3.3	3.6	4.5	3	-8
Cooperative State Research Service	0	0	0	0	0	0	—	—
Interior	24.0	23.2	22.4	30.7	24.8	29.6	3	-4
Geological Survey	9.9	7.4	4.4	4.9	2.3	0.5	34	82
National Science Foundation	0	0	0	0	0	2.2	—	—
Others	397.2	487.6	552.8	583.0	492.7	508.1	-19	-5
TOTAL	\$42,368.5	\$35,607.1	\$32,202.1	\$27,246.1	\$24,458.0	\$23,410.4	19%	13%
ANNUAL CHANGE	19%	11%	18%	11%	4%	3%		

Note: Fiscal years. a Estimated. b Includes Defense Advanced Research Projects Agency, Defense Nuclear Agency, and others. Source: National Science Foundation

UNIVERSITY RESEARCH: Not much change in funding overall, but chemistry gets more

Federal obligations, \$ millions	1987*	1988*	1985	1984	1983	1982	Annual change	
							1988-87	1982-87
Life sciences	\$3124.8	\$3288.8	\$3192.2	\$2800.2	\$2460.0	\$2205.0	-5%	7%
Physical sciences	816.9	757.2	749.7	697.8	596.5	559.1	8	8
Chemistry	287.0	259.7	266.8	242.3	205.7	189.6	11	9
Physics	429.8	406.5	401.8	375.2	328.8	306.0	6	7
Engineering	577.8	559.0	507.1	474.2	408.7	351.5	3	10
Chemical	43.7	48.8	45.6	51.2	23.6	19.4	-10	18
Metallurgy and materials	121.1	125.9	107.2	87.7	86.0	75.3	-4	10
Environmental sciences	410.2	380.2	361.1	319.5	316.9	274.7	8	8
Mathematics and computer sciences	338.3	302.8	253.1	181.6	172.4	139.7	12	19
Other sciences	360.6	367.4	347.8	304.1	297.8	255.7	-2	7
TOTAL	\$5628.6	\$5655.4	\$5411.0	\$4777.4	\$4252.3	\$3795.7	0%	8%
ANNUAL CHANGE	0%	5%	13%	12%	12%	2%		

Note: Fiscal years. a Estimated. Source: National Science Foundation

UNIVERSITY BASIC RESEARCH: More than half goes for life sciences

Federal obligations, \$ million:	1987*	1988*	1985	1984	1983	1982	Annual change	
							1988-87	1982-87
Life sciences	\$2267.5	\$2379.2	\$2306.8	\$1979.6	\$1701.7	\$1483.7	-5%	9%
Physical sciences	714.1	646.7	628.8	581.9	502.2	455.3	10	9
Chemistry	259.3	227.9	234.9	212.1	181.9	165.3	14	9
Physics	362.3	332.8	317.0	293.9	264.7	238.6	9	9
Engineering	448.0	419.7	386.6	340.3	295.5	259.0	7	12
Chemical	33.7	29.9	27.6	29.6	18.9	16.8	13	15
Metallurgy and materials	108.7	116.3	95.8	79.9	76.8	69.6	-7	9
Environmental sciences	380.4	350.2	330.7	288.9	284.3	256.0	9	8
Mathematics and computer sciences	202.1	202.0	172.1	152.6	146.8	118.8	0	11
Other sciences	202.2	187.8	169.0	147.4	147.2	120.5	8	11
TOTAL	\$4214.3	\$4185.5	\$3974.0	\$3490.7	\$3077.7	\$2693.3	1%	9%
ANNUAL CHANGE	1%	5%	14%	13%	14%	9%		

Note: Fiscal years. a Estimated. Source: National Science Foundation

BASIC RESEARCH IN PHYSICAL SCIENCE: NSF, Defense score biggest gains for chemistry

Federal obligations, \$ millions	1987 ^a		1986 ^a		1985		1984		1983	
	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry
Energy	\$ 852.5	\$112.1	\$ 743.1	\$108.5	\$ 736.1	\$102.3	\$ 688.4	\$108.4	\$ 639.2	\$104.3
National Aeronautics & Space Administration	535.6	7.8	437.7	5.1	377.9	10.2	338.7	5.4	329.5	7.7
National Science Foundation	380.7	128.9	340.6	109.9	347.9	112.7	330.2	106.8	283.5	88.5
Defense	213.2	82.1	212.7	73.9	185.5	70.1	212.2	60.0	198.4	55.6
Navy	87.5	30.3	84.8	26.1	73.9	26.7	100.4	20.7	98.0	18.7
Air Force	77.6	32.7	63.9	27.0	54.1	22.8	48.3	20.3	39.3	17.5
Army	46.2	19.0	51.7	20.8	54.3	20.6	59.8	19.1	58.7	19.4
Defense agencies ^b	1.8	0	12.3	0	3.2	0	3.7	0	2.5	0
Health & Human Services	81.4	73.4	86.8	78.3	83.6	75.4	72.0	65.0	61.8	55.0
National Institutes of Health	79.3	71.4	84.6	76.1	81.5 ^a	73.3 ^a	70.8	63.8	60.9	54.2
Alcohol, Drug Abuse & Mental Health Administration	2.1	2.0	2.2	2.1	2.1	2.1	1.2	1.2	0.9	0.9
Agriculture	33.5	33.3	35.6	33.5	35.6	33.6	45.4	43.5	40.0	38.2
Agricultural Research Service	26.9	25.5	25.0	23.7	25.2	23.9	37.4	36.0	33.5	32.2
Cooperative State Research Service	4.6	4.6	6.1	6.1	6.4	6.4	5.4	5.4	4.1	4.1
Forest Service	3.9	3.2	4.6	3.7	4.0	3.3	2.6	2.1	2.4	1.9
Commerce	15.9	5.2	18.1	6.7	19.7	7.2	16.3	4.8	15.7	4.7
National Bureau of Standards	15.9	5.2	17.6	6.3	18.9	6.4	16.3	4.8	15.7	4.6
Interior	7.0	5.5	7.9	6.3	7.6	6.0	7.1	5.6	2.9	1.8
Geological Survey	7.0	5.5	7.9	6.3	7.6	6.0	7.1	5.6	2.6	1.8
Environmental Protection Agency	3.4	2.9	3.6	3.1	3.5	3.0	3.0	3.0	2.3	1.9
Others	17.8	0.4	15.6	0.2	16.6	0.3	14.7	0.9	13.5	3.5
TOTAL	\$2141.0	\$451.3	\$1901.7	\$425.4	\$1814.0	\$420.8	\$1728.0	\$403.4	\$1587.2	\$362.2
ANNUAL CHANGE	13%	6%	5%	1%	5%	4%	9%	11%	14%	16%

Note: Fiscal years. a Estimated. b Includes Defense Advanced Research Projects Agency, Defense Nuclear Agency, and others. Source: National Science Foundation

ENGINEERING RESEARCH: Support for chemical engineering drops sharply this year but is still twice

\$ Millions	1987 ^a			1986 ^a			1985	
	Engineering	Chemical engineering	Metallurgy & materials	Engineering	Chemical engineering	Metallurgy & materials	Engineering	Chemical engineering
Defense	\$1624.9	\$ 54.5	\$281.1	\$1523.9	\$ 50.3	\$277.9	\$1502.0	\$ 53.3
Air Force	488.1	3.2	36.9	472.7	3.3	34.3	423.9	1.7
Army	434.9	23.5	41.3	336.1	20.9	37.7	344.3	26.7
Navy	409.9	27.8	120.1	408.5	26.1	121.1	421.2	24.8
Defense agencies ^b	292.1	0	82.8	306.6	0	84.8	312.6	0.1
National Aeronautics & Space Administration	1270.0	0.9	23.4	1021.6	0.8	17.7	931.6	0.6
Energy	322.0	58.8	73.6	463.6	126.2	68.7	511.3	136.6
National Science Foundation	231.3	41.2	47.6	195.6	34.4	42.1	193.3	32.6
Interior	69.6	4.4	25.4	94.9	4.9	40.9	100.2	4.8
Transportation	44.1	0.4	1.0	53.9	0.7	2.5	49.4	0.6
Environmental Protection Agency	43.7	17.5	2.5	45.6	18.1	2.7	44.8	18.0
Commerce	38.0	2.3	10.5	43.7	1.9	11.2	38.8	1.7
Agriculture	28.9	5.8	0	29.1	5.8	0	28.7	5.6
Others	185.3	0.3	0.5	212.5	0.4	0.4	227.4	0.4
TOTAL	\$3857.8	\$186.0	\$465.5	\$3684.4	\$243.5	\$464.1	\$3628.5	\$254.1
ANNUAL CHANGE	5%	-24%	0%	2%	-4%	6%	0%	76%

Note: Fiscal years. a Estimated. b Includes Defense Advanced Projects Agency, Defense Nuclear Agency, and others. Source: National Science Foundation

APPLIED RESEARCH IN PHYSICAL SCIENCE: Chemical funding down slightly this year

\$ Millions ^a	1987 ^a		1986 ^a		1985		1984		1983	
	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry
Energy	\$ 511.6	\$ 24.9	\$ 538.7	\$ 37.3	\$ 606.1	\$ 40.6	\$ 603.5	\$ 32.0	\$ 584.8	\$ 13.3
Defense	434.8	102.7	415.1	93.4	412.0	86.3	477.2	79.8	562.0	66.3
Army	129.7	71.0	116.4	62.1	124.2	57.5	77.4	47.2	86.9	39.9
Air Force	59.0	17.0	60.2	17.3	57.5	16.7	58.6	16.4	54.5	13.7
Navy	55.6	13.9	53.9	13.4	50.7	11.6	69.2	15.9	135.2	12.3
Defense agencies ^c	190.5	0.8	184.6	0.6	179.6	0.4	272.1	0.3	285.4	0.3
National Aeronautics & Space Administration	81.9	6.0	79.9	6.0	76.3	6.1	25.6	1.9	40.4	1.7
Commerce	34.0	9.8	35.1	10.4	35.2	10.5	36.9	10.5	33.9	9.3
National Bureau of Standards	25.1	8.5	25.0	8.4	25.3	9.0	28.1	9.3	26.7	8.1
National Oceanic & Atmospheric Administration	8.9	1.3	10.1	2.0	9.9	1.4	8.9	1.3	7.2	1.2
Health & Human Services	26.5	23.0	28.4	24.6	27.3	23.6	24.7	21.3	22.6	19.2
National Institutes of Health	24.6	21.1	26.1	22.4	25.4 ^a	21.8 ^a	23.6	20.3	21.5	18.1
Alcohol, Drug Abuse & Mental Health Administration	1.9	1.9	2.3	2.2	1.9	1.9	1.1	1.1	1.2	1.1
Agriculture	24.2	22.2	25.8	23.8	26.4	24.4	27.3	25.5	27.6	25.6
Agricultural Research Service	13.9	12.9	12.9	12.0	13.1	12.2	16.9	15.6	18.6	17.2
Cooperative State Research Service	6.8	6.8	9.3	9.3	9.7	9.7	8.1	8.1	6.7	6.7
Forest Service	3.5	2.4	3.6	2.5	3.5	2.4	2.4	1.8	2.3	1.7
Environmental Protection Agency	15.4	14.1	16.1	14.9	15.7	14.5	13.8	12.9	13.9	12.8
Interior	14.5	12.5	16.2	13.9	15.5	13.3	15.7	13.6	5.5	4.4
Geological Survey	14.5	12.5	16.2	13.9	15.5	13.3	14.9	12.8	4.7	3.8
National Science Foundation	12.5	3.1	11.3	2.7	11.8	2.9	10.9	3.1	9.4	3.9
Others	3.9	1.3	3.3	1.0	3.8	1.4	5.4	2.4	4.2	1.6
TOTAL	\$1159.3	\$219.6	\$1170.0	\$228.0	\$1230.1	\$223.6	\$1241.0	\$203.0	\$1304.3	\$158.1
ANNUAL CHANGE	-1%	-4%	-5%	2%	-1%	10%	-5%	28%	1%	-7%

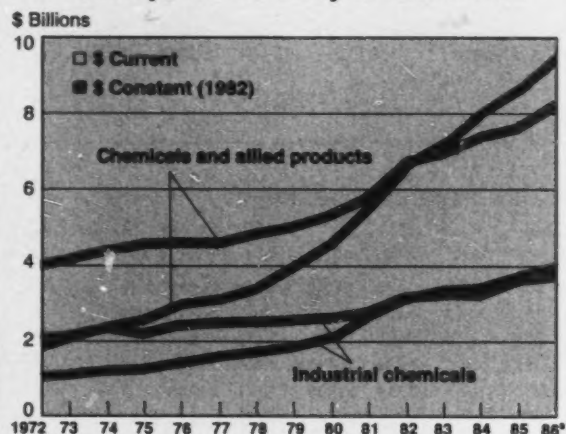
Note: Fiscal years. a Estimated. b Obligations. c Includes Defense Advanced Research Projects Agency, Defense Nuclear Agency, and others. Source: National Science Foundation

the level of five years ago

1985			1984			1983			1982		
Metalurgy & materials	Engineering	Chemical engineering	Metalurgy & materials	Engineering	Chemical engineering	Metalurgy & materials	Engineering	Chemical engineering	Metalurgy & materials	Engineering	Chemical engineering
\$260.9	\$1488.4	\$ 38.4	\$180.3	\$1573.9	\$ 44.9	\$179.3	\$1473.3	\$39.0	\$159.3		
28.6	439.5	3.5	30.3	419.3	3.1	38.2	387.3	2.9	35.1		
42.2	324.8	23.5	35.5	318.9	29.3	28.4	297.2	24.4	31.7		
121.1	398.4	11.3	53.9	395.5	11.9	50.0	378.0	11.6	49.3		
69.0	325.7	0.2	60.6	440.2	0.6	62.8	410.8	0.2	43.1		
15.8	967.8	0.3	14.2	799.6	1.0	19.1	771.7	0.4	16.2		
68.4	439.0	46.1	68.7	440.2	51.9	62.6	420.8	1.1	61.2		
42.7	164.9	27.7	27.3	142.5	21.5	27.3	129.9	18.8	26.4		
39.8	111.4	4.5	42.2	91.4	0.4	31.5	87.1	1.4	32.8		
1.5	51.1	1.2	1.9	56.1	1.0	1.4	48.3	0.5	1.0		
2.6	37.8	17.8	0	47.8	16.7	3.5	76.4	26.0	5.2		
6.9	35.3	1.8	6.4	37.4	1.3	7.8	32.0	2.0	7.1		
0	56.7	6.4	0	54.7	6.2	0	51.2	5.8	0		
0.5	271.7	0.3	0.1	273.4	0.1	0	295.8	0.1	0		
\$439.1	\$3624.1	\$144.5	\$341.1	\$3517.0	\$145.0	\$332.5	\$3386.5	\$95.1	\$309.1		
29%	3%	0%	3%	4%	53%	8%	10%	36%	21%		

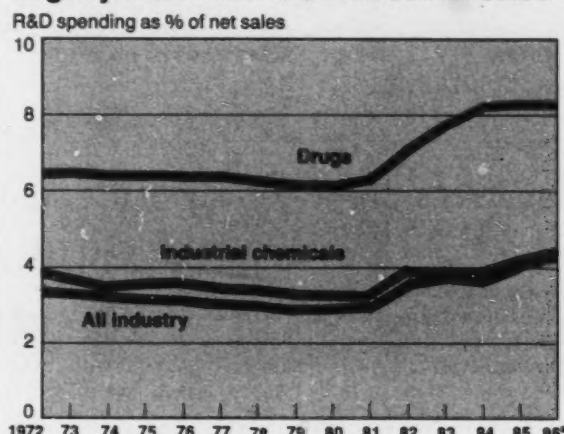
Industrial support for R&D up only 5%

With inflation low, chemical companies' R&D outlays rise smartly in real terms



* C&EN estimates. Source: National Science Foundation

Outlays for industrial R&D are rising at slightly faster rate than industrial sales



* C&EN estimates. Source: National Science Foundation

TOTAL FUNDS FOR INDUSTRIAL R&D: Drug producers continue to set a fast pace

\$ Millions	1986*	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	Annual change 1985-86 1976-86
Chemicals and allied products	\$ 9,500	\$ 8,667	\$ 8,028	\$ 7,293	\$ 6,659	\$ 5,625	\$ 4,636	\$ 4,038	\$ 3,580	\$ 3,202	\$ 3,017	10% 12%
Industrial chemicals	4,150	3,915	3,512	3,411	3,301	2,802	2,197	1,962	1,798	1,668	1,524	6 11
Drugs	4,070	3,548	4,516	3,882	3,358	2,823	1,777	1,517	1,308	1,117	1,091	15 14
Other chemicals	1,280	1,204					662	559	474	417	401	6 12
Other industries	74,900	69,512	63,442	56,110	51,337	46,185	39,869	34,188	29,724	26,823	23,980	8 12
TOTAL	\$84,400	\$78,179	\$71,470	\$63,403	\$57,996	\$51,810	\$44,505	\$38,226	\$33,304	\$29,825	\$26,967	8% 12%

* C&EN estimates. Source: National Science Foundation

COMPANY FUNDS FOR INDUSTRIAL R&D: Chemical industry spends about a sixth of the total

\$ Millions	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	Annual change 1984-85 1975-85
Chemicals and allied products	\$ 8,352	\$ 7,797	\$ 6,845	\$ 6,226	\$ 5,205	\$ 4,264	\$ 3,692	\$ 3,250	\$ 2,907	\$ 2,751	\$ 2,490	7% 13%
Industrial chemicals	3,618	3,289	2,970	2,879	2,393	1,856	1,617	1,473	1,387	1,275	1,173	10 12
Drugs	3,545	3,381	2,937	2,490	2,064	1,756	2,075	1,777	1,520	1,476	1,317	5 14
Other chemicals	1,189	1,126	938	856	747	653						6
Other industries	43,344	40,511	36,016	33,286	30,223	26,212	22,016	18,865	16,433	14,685	13,092	7 13
TOTAL	\$51,696	\$48,308	\$42,861	\$39,512	\$35,428	\$30,476	\$25,708	\$22,115	\$19,340	\$17,436	\$15,582	7% 13%

Source: National Science Foundation

FEDERAL FUNDS FOR INDUSTRIAL R&D: Of little significance for the chemical industry

\$ Millions	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	Annual change	
												1984-85	1975-85
Chemicals and allied products	\$ 316	\$ 232	\$ 448	\$ 434	\$ 421	\$ 372	\$ 346	\$ 330	\$ 295	\$ 266	\$ 236	36%	3%
Industrial chemicals	298	223	440	423	409	341	345	325	281	249	218	4	3
Drugs and other chemicals	18	9	8	11	12	31	1	5	14	17	18	100	0
Other industries	26,168	22,930	20,094	18,049	15,961	13,657	12,172	10,859	10,190	9,295	8,369	14	12
TOTAL	\$26,484	\$23,162	\$20,542	\$18,483	\$16,382	\$14,029	\$12,518	\$11,189	\$10,485	\$9,561	\$8,605	14%	12%

Source: National Science Foundation

R&D BY U.S. COMPANIES ABROAD: Relatively small but expanding steadily

\$ Millions	1986 ^a	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	Annual change	
												1985-86	1976-86
Chemicals and allied products	\$ 900	\$ 816	\$ 793	\$ 732	\$ 684	\$ 715	\$ 603	\$ 500	\$ 395	\$ 332	\$ 312	10%	11%
Industrial and other chemicals	440	409	363	354	313	287	245	199	151	133	108	8	15
Drugs	460	406	430	378	371	428	357	301	244	199	204	13	8
Other industries	3100	2931	2786	2544	2413	2679	2562	2254	1814	1545	1347	6	9
TOTAL	\$4000	\$3747	\$3579	\$3276	\$3097	\$3393	\$3165	\$2754	\$2209	\$1877	\$1659	7%	9%

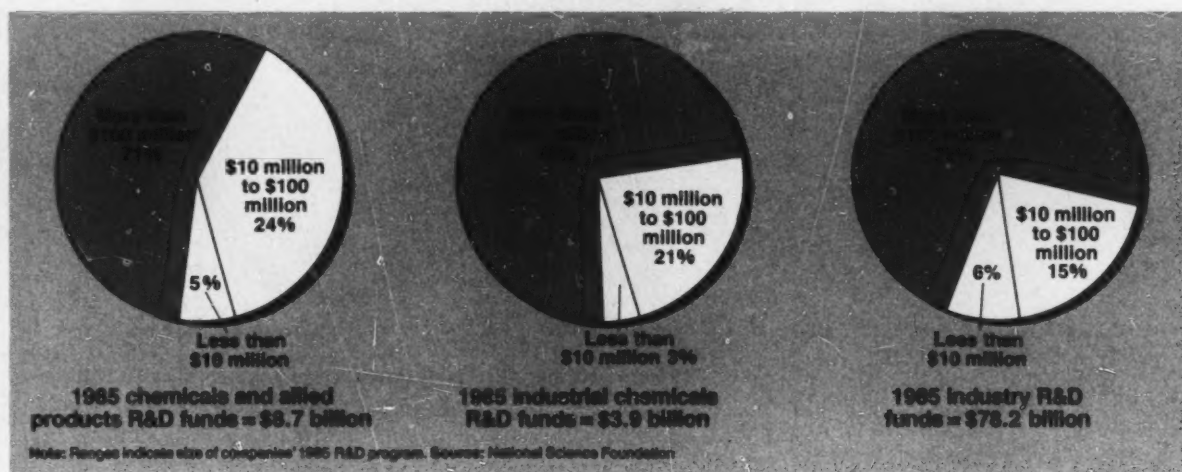
^a C&EN estimates. Source: National Science Foundation

CHEMICAL R&D SPENDING: Slight rise last year largely reflects Carbide's major divestments

\$ Millions	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1986 R&D spending as % of sales
Air Products	\$ 61	\$ 51	\$ 44	\$ 40	\$ 37	\$ 32	\$ 30	\$ 24	\$ 23	\$ 24	\$ 19	3.1%
American Cyanamid	278	251	232	208	185	166	148	130	108	96	83	7.3
Dow Chemical	605	547	507	492	460	404	314	269	232	203	188	5.4
Du Pont ^a	1070	1080	1000	875	775	647	591	509	461	367	353	9.0
Ethyl	47	47	40	39	39	37	34	29	25	28	25	3.0
W. R. Grace	94	92	81	73	64	57	45	42	37	32	28	2.5
Hercules	71	76	72	74	74	65	57	50	43	40	37	2.7
International Flavors	39	34	32	32	31	30	29	27	24	20	16	6.3
Lubrizol	51	44	33	37	36	33	28	23	21	19	17	5.2
Monsanto	596	470	370	290	264	233	208	161	136	132	114	8.7
Nalco Chemical	33	32	32	30	33	30	28	21	17	14	12	4.5
Olin	56	53	52	49	45	38	31	26	25	25	23	3.3
Pennwalt	45	39	36	33	31	27	24	22	23	21	19	4.1
Petrolite	12	12	12	13	10	8	7	6	5	5	4	4.3
PPG Industries	204	176	150	127	127	119	103	83	70	61	56	4.3
Rohm & Haas	133	124	109	100	92	77	67	54	49	45	43	6.4
Union Carbide ^b	148	275	265	245	240	207	166	161	156	156	143	2.4
TOTAL	\$3543	\$3403	\$3067	\$2757	\$2543	\$2210	\$1910	\$1637	\$1455	\$1288	\$1180	5.7%
ANNUAL CHANGE	4%	11%	11%	8%	15%	16%	17%	13%	13%	9%	8%	

^a Figures exclude petroleum and coal segments. ^b Union Carbide divested a substantial part of its businesses in 1986; on a pro forma basis, R&D spending was \$181 million in 1985 and \$178 million in 1984. Source: Company data

Companies whose annual R&D budgets top \$100 million do more than 70% of all R&D

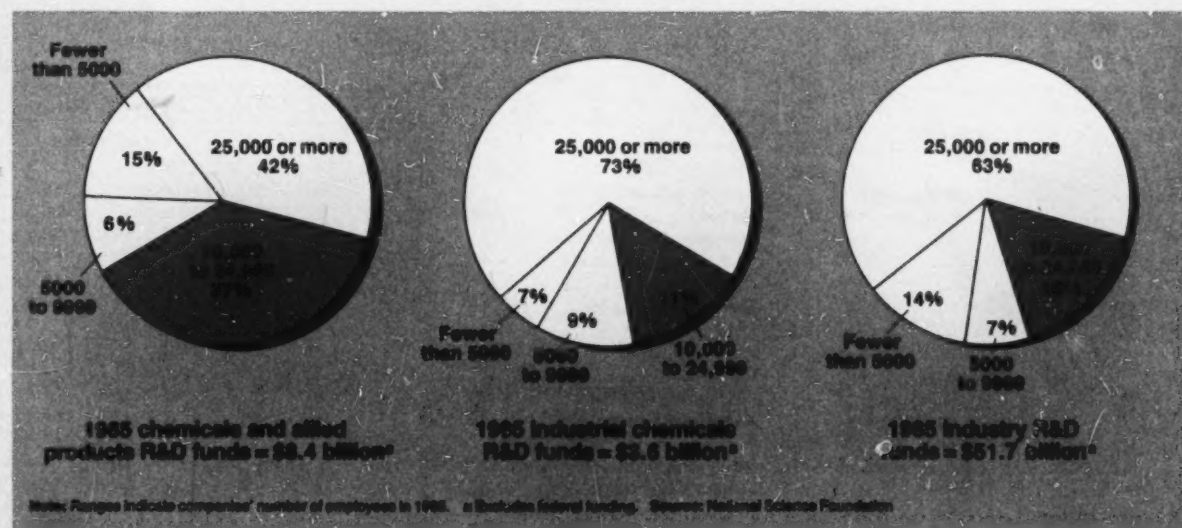


R&D SCIENTISTS AND ENGINEERS IN INDUSTRY: Increasing faster for chemicals

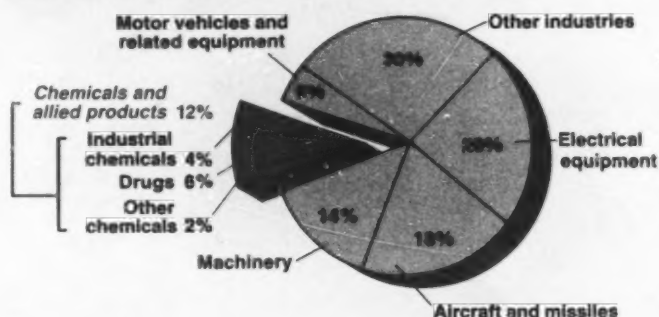
Thousands*	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	Annual change	
												1985-86	1976-86
Chemicals and allied products	71.3	67.0	67.1	66.0	61.6	54.7	51.4	50.0	48.3	46.4	44.4	6%	5%
Industrial chemicals	26.8	25.0	26.7	27.2	25.9	21.6	20.9	21.4	21.3	20.6	20.1	7	3
Drugs	33.3	30.7	30.1	28.2	25.6	23.3	21.6	20.8	19.5	17.8	16.6	8	7
Other chemicals	11.2	11.3	10.3	10.6	10.1	9.8	8.9	7.8	7.5	8.0	7.8	-1	4
Other industries	509.0	493.2	477.4	456.1	448.2	433.1	399.2	373.9	356.1	336.4	320.0	3	5
TOTAL	580.3	560.2	544.5	522.1	509.8	487.8	450.6	423.9	404.4	382.8	364.4	4%	5%

Note: Data as of January of each year. * Full-time equivalent. Source: National Science Foundation

Chemical companies with 10,000 to 25,000 employees perform more than a third of R&D



Chemical and drug companies provide jobs for 12% of all industrial scientists and engineers



1986 total industrial R&D scientists and engineers^a = 580,300

^a Full-time equivalent, as of January 1986. Source: National Science Foundation

R&D SCIENTISTS AND ENGINEERS PER 1000 EMPLOYEES: At new high in chemical industry

	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975
Chemicals and allied products	55	54	54	51	44	42	42	43	42	40	41
Industrial chemicals	42	44	45	44	37	36	36	38	38	36	38
Drugs	93	88	82	74	66	60	62	65	62	64	59
Other chemicals	38	37	36	36	33	30	27	27	29	28	29
All industry	36	38	35	33	29	27	27	27	27	27	26

Source: National Science Foundation

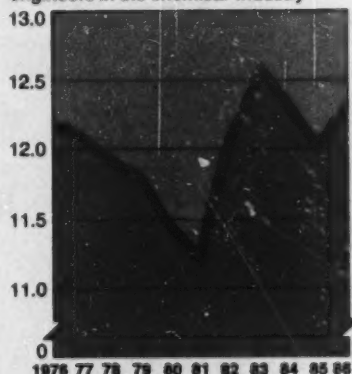
COST PER INDUSTRIAL R&D SCIENTIST OR ENGINEER: More than doubled in past decade

\$ Thousands	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975
Chemicals and allied products	\$125.2	\$119.1	\$109.6	\$104.4	\$ 98.6	\$ 87.4	\$79.6	\$72.8	\$67.6	\$66.5	\$60.9
Industrial chemicals	151.1	135.1	126.6	124.3	118.0	103.4	92.8	84.2	79.6	74.7	67.5
Drugs	a	111.2	100.7	a	a	79.2	71.4	64.8	59.9	63.4	60.9
Other chemicals	a	a	a	a	a	66.5	66.5	61.6	53.8	50.8	43.2
All industry	\$137.0	\$129.7	\$118.9	\$112.4	\$103.9	\$ 94.9	\$87.4	\$80.4	\$75.8	\$72.2	\$66.5

^a Not separately available but included in chemicals and allied products. Source: National Science Foundation

Chemical firms' share of R&D personnel up in 1986

% of total industrial R&D scientists and engineers in the chemical industry^a



^a Full-time equivalent, as of January of each year. Source: National Science Foundation

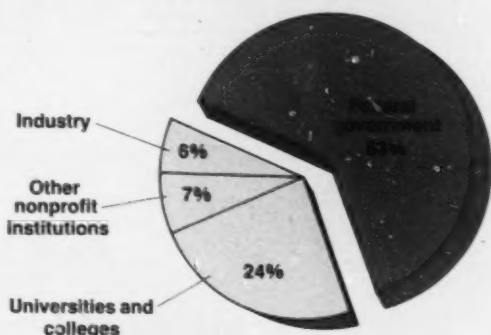
CHEMISTS IN INDUSTRY: Drugs biggest employer

Industry	% of industrial chemists				Mean salary (\$ thousands) ^a		
	All chemists	B.S.	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Pharmaceuticals ^b	18%	17%	20%	17%	\$40.3	\$42.4	\$57.2
Specialty chemicals	15	13	12	16	41.8	45.7	53.3
Basic chemicals	7	4	5	9	40.8	43.8	58.2
Plastics	5	5	6	6	42.3	47.6	56.6
Petroleum and natural gas	5	3	4	6	45.1	49.4	63.6
Agricultural chemicals	4	2	4	5	37.8	46.0	54.4
Coatings	4	5	4	3	41.6	47.7	50.6
Electronics	4	3	4	4	41.2	46.2	56.9
Food	3	5	4	2	39.8	46.2	56.5
Metals and minerals	2	4	2	1	40.2	38.8	47.0
Rubber	2	3	2	2	40.7	37.8	54.7
Biochemical products	2	1	2	2	35.1	35.5	57.5
Soaps and detergents	1	1	1	2	36.3	47.2	59.8
Paper	1	1	1	1	37.2	37.8	54.8
Other manufacturing	17	20	17	16	41.2	44.1	55.1
Nonmanufacturing	10	13	12	7	40.7	41.0	50.1

^a As of March 1, 1987; to facilitate comparison, mean salaries are adjusted for differences in average length of experience for each group. ^b Includes personal care products. Source: ACS survey

University R&D increased 8% last year

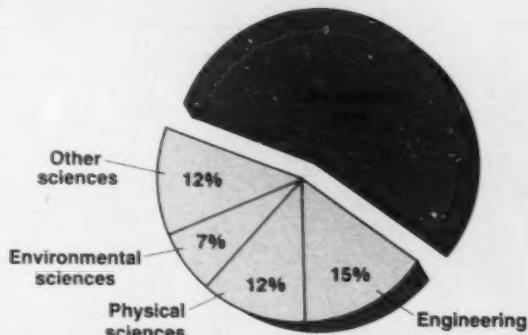
Nearly two thirds of academic R&D funding comes from federal government



Estimated fiscal 1986 academic R&D expenditures = \$10.25 billion

Source: National Science Foundation

More than half of academic R&D is in the life sciences



Estimated fiscal 1986 academic R&D expenditures = \$10.25 billion

Source: National Science Foundation

CHARACTER OF UNIVERSITY R&D SPENDING: Basic research gets two thirds

\$ Millions	1986*	1985	1984	1983	1982	1981	1980	1979	1978*	1977	1976	Annual change	
												1985-86	1976-86
Basic research	\$ 6,900	\$6377	\$5638	\$5269	\$4857	\$4576	\$4026	\$3612	\$3176	\$2800	\$2549	8%	10%
Applied research	2,760	2580 ^a	2370 ^a	2101	2004	1866	1691	1465	1213	1067	1015	7	11
Development	590	517 ^a	495 ^a	437	415	377	343	284	236	200	164	8	14
TOTAL	\$10,250	\$9504	\$8503	\$7807	\$7276	\$6819	\$6060	\$5361	\$4625	\$4067	\$3729	8%	11%
ANNUAL CHANGE	8%	12%	9%	7%	7%	13%	13%	16%	14%	9%	9%		

Note: Data for institutional fiscal years. a C&EN estimates. b Estimated, based on data from Ph.D.-granting institutions only. Source: National Science Foundation

SOURCE OF UNIVERSITY R&D FUNDS: Federal share is largest, but it is falling

\$ Millions	1986*	1985	1984	1983	1982	1981	1980	1979	1978*	1977	1976	Annual change	
												1985-86	1976-86
Federal government	\$ 6,400	\$6003	\$5388	\$4960	\$4752	\$4562	\$4096	\$3595	\$3059	\$2726	\$2512	7%	10%
Industry	580	538	458	379	334	291	237	194	170	139	123	8	17
Universities	2,500	2258	2024	1881	1690	1520	1319	1198	1037	888	810	11	12
Other sources	770	704	633	587	500	446	409	374	359	314	284	9	10
TOTAL	\$10,250	\$9504	\$8503	\$7807	\$7276	\$6819	\$6060	\$5361	\$4625	\$4067	\$3729	8%	11%

Note: Data for institutional fiscal years. a C&EN estimates. b Estimated, based on data from Ph.D.-granting institutions only. Source: National Science Foundation

FIELDS OF UNIVERSITY R&D SPENDING: Biggest growth for computers and math

\$ Millions	1986 ^a	1985	1984	1983	1982	1981	1980	1979	1978 ^b	1977	1976	Annual change	
												1985-86	1978-86
All sciences	\$ 8,730	\$8120.5	\$7296.5	\$6695.5	\$6250.2	\$5857.6	\$5195.4	\$4593.0	\$4023.6	\$3568.5	\$3297.3	8%	10%
Life	5,510	5138.5	4607.3	4233.0	3972.4	3673.1	3216.9	2832.5	2538.0	2258.8	2101.7	7	10
Physical	1,230	1136.6	996.9	898.9	824.3	766.3	677.4	601.9	469.4	423.5	379.4	8	12
Physics	600	549.9	470.8	414.4	366.2	357.2	322.2	292.0	235.1	201.7	183.1	9	13
Chemistry	435	414.5	371.2	336.0	309.4	285.1	244.0	206.4	183.1	159.4	140.1	5	12
Environmental	755	707.0	649.5	620.5	559.3	550.3	509.1	452.9	379.4	319.4	288.5	7	10
Computer	340	277.7	222.7	175.5	149.5	113.1	114.2	97.9	67.4	55.6	44.5	22	23
Mathematical	145	129.4	124.4	108.4	98.9	89.1	78.6	78.5	58.8	52.3	42.5	12	13
Others	750	731.3	635.7	659.1	645.8	645.8	599.1	539.3	483.7	458.9	440.7	3	5
Engineering	1,520	1383.2	1206.4	1111.3	1025.8	961.0	864.9	768.4	601.1	498.5	431.7	10	13
Chemical	115	109.0	96.2	90.8	83.6	83.2	67.6	na	na	na	na	6	na
TOTAL	\$10,250	\$9503.7	\$8503.0	\$7806.8	\$7276.1	\$6818.6	\$6060.3	\$5361.4	\$4624.7	\$4067.0	\$3729.0	8%	11%
ANNUAL CHANGE	8%	12%	9%	7%	7%	13%	13%	16%	14%	9%	9%		

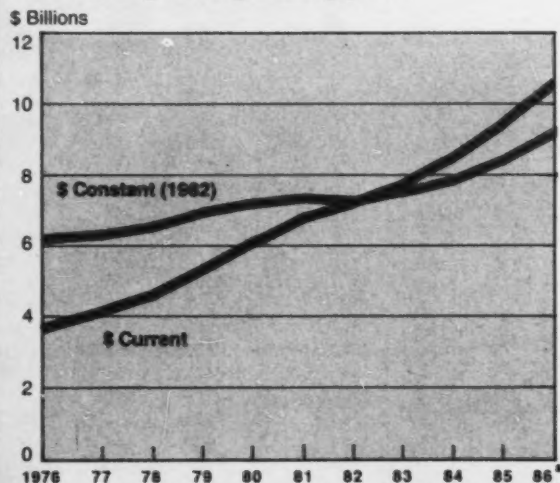
Note: Data for institutional fiscal years. a C&EN estimates. b NSF estimates, based on data from Ph.D.-granting institutions only. na = not available. Source: National Science Foundation

FEDERALLY FINANCED R&D SPENDING AT UNIVERSITIES: Growth slows in physical science

\$ Millions	1986 ^a	1985	1984	1983	1982	1981	1980	1979	1978 ^b	1977	1976	Annual change	
												1985-86	1978-86
All sciences	\$5420	\$5145.0	\$4609.4	\$4221.8	\$4054.0	\$3899.3	\$3500.6	\$3068.9	\$2651.2	\$2389.4	\$2221.3	5%	9%
Life	3290	3138.7	2793.9	2565.3	2494.4	2364.2	2094.0	1818.8	1626.4	1474.0	1380.8	5	9
Physical	920	883.3	779.3	698.5	650.0	619.0	554.8	490.7	392.3	338.8	305.4	4	12
Physics	480	454.7	387.9	340.0	306.2	308.7	279.9	252.5	199.2	171.9	156.1	6	12
Chemistry	320	308.4	278.9	248.6	231.1	216.8	189.4	156.5	138.0	121.5	107.9	4	11
Environmental	500	480.7	451.5	427.9	392.2	392.7	372.5	329.2	275.1	238.6	211.8	4	9
Computer	230	193.1	161.6	127.8	107.0	93.5	77.0	69.2	41.2	37.5	32.9	19	21
Mathematical	115	96.1	91.3	76.7	72.1	67.9	61.1	60.4	44.1	40.6	32.9	20	13
Others	365	353.1	331.8	325.5	338.4	361.9	341.2	300.6	272.0	259.9	257.4	3	4
Engineering	980	857.5	778.6	737.9	698.2	662.5	595.4	526.4	407.5	336.7	290.5	14	13
Chemical	65	57.9	54.4	52.1	49.6	55.2	46.1	na	na	na	na	12	na
TOTAL	\$6409	\$6002.6	\$5388.0	\$4959.7	\$4752.2	\$4561.8	\$4096.0	\$3595.3	\$3058.7	\$2726.1	\$2511.9	7%	10%
ANNUAL CHANGE	7%	11%	9%	4%	4%	11%	14%	18%	12%	9%	10%		

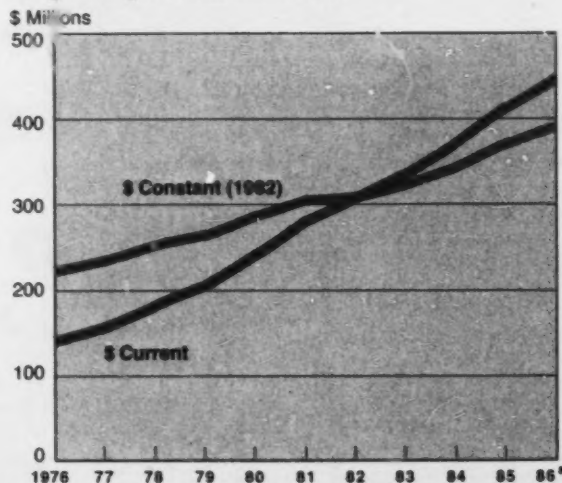
Note: Data for institutional fiscal years. a C&EN estimates. b NSF estimates, based on data from Ph.D.-granting institutions only. na = not available. Source: National Science Foundation.

Money for academic R&D, in constant dollars, is growing strongly ...



Note: Data for institutional fiscal years. a C&EN estimates. Source: National Science Foundation

... and funding for R&D in chemistry also forges higher in real terms



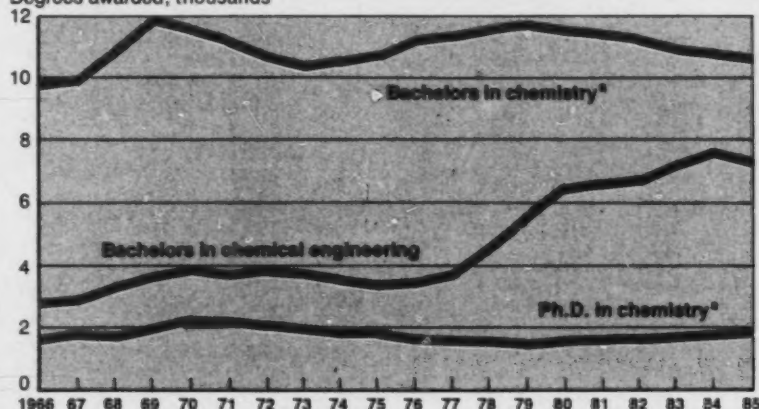
TOP 10 UNIVERSITIES IN R&D SPENDING: 21% of total goes to top 10 institutions

\$ Millions, fiscal 1985	Physical sciences	Chemistry ^a	Engineering	Environmental sciences	Life sciences	Math and computer sciences	Other sciences ^b	Total
1 Johns Hopkins U	\$ 58.3	\$ 4.2	\$ 116.8	\$ 28.3	\$ 99.6	\$ 71.7	\$ 13.9	\$ 388.6
2 Massachusetts Inst. of Technology	70.7	12.4	103.8	12.5	31.1	13.4	11.5	243.0
3 U of Wisconsin, Madison	23.7	5.2	21.8	17.8	115.8	7.4	21.9	208.4
4 Cornell U	36.2	6.3	30.6	5.2	114.5	6.6	10.1	203.2
5 Stanford U	35.2	7.1	58.3	3.2	83.1	14.1	5.3	199.2
6 U of Minnesota	11.2	3.3	18.1	3.7	127.2	3.4	9.7	173.3
7 U of Washington	11.6	2.0	11.9	18.0	99.8	3.8	18.9	164.0
8 U of Michigan	11.4	2.3	23.0	9.6	79.3	3.7	36.7	163.7
9 U of California, Berkeley	31.8	9.9	31.9	2.4	62.6	2.8	18.4	149.9
10 U of California, Los Angeles	15.5	6.7	18.5	8.8	93.3	1.2	12.4	149.7
TOTAL, TOP 10 INSTITUTIONS	\$ 305.7	\$ 59.4	\$ 434.7	\$109.4	\$ 906.4	\$128.1	\$158.7	\$2043.0
TOTAL, ALL INSTITUTIONS	\$1136.6	\$308.4	\$1383.2	\$707.0	\$5138.5	\$407.1	\$731.3	\$9503.7

^a Included in physical sciences. ^b Includes social sciences, psychology, and other sciences not listed separately. Source: National Science Foundation

Fewer degrees awarded at undergraduate level

Degrees awarded, thousands



Note: Academic fiscal years. ^a Excludes biochemistry and geochemistry. Source: National Center for Education Statistics

CHEMICAL DEGREES: Doctorates increase

Academic fiscal year	Bachelors	Masters	Ph.D.s
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DEGREES IN CHEMISTRY^a

1966	9,735	1839	1571
1967	9,872	1831	1744
1968	10,847	2014	1757
1969	11,807	2070	1941
1970	11,617	2146	2208
1971	11,183	2284	2160
1972	10,721	2259	1971
1973	10,226	2230	1882
1974	10,525	2138	1828
1975	10,649	2006	1824
1976	11,107	1796	1623
1977	11,322	1775	1571
1978	11,474	1892	1525
1979	11,643	1765	1518
1980	11,446	1733	1551
1981	11,347	1654	1622
1982	11,062	1751	1722
1983	10,746	1604	1746
1984	10,704	1667	1744
1985	10,482	1719	1789

TOP 10 UNIVERSITY R&D CENTERS: 40% of funding goes to support work in physical sciences

\$ Millions, fiscal 1985	Physical sciences	Engineering	Environmental sciences	Math and computer sciences	Total ^a
1 Lawrence Livermore Lab	\$ 230.5	\$ 432.2	\$ 26.4	\$ 95.0	\$ 805.3
2 Los Alamos National Lab	335.8	233.0	16.9	64.1	704.0
3 Jet Propulsion Lab	72.7	295.2	61.8	236.5	666.2
4 Lincoln Lab	50.3 ^b	186.2 ^b	0	27.8 ^b	264.5
5 Argonne National Lab	69.3	116.5	24.5	2.3	223.7
6 Brookhaven National Lab	134.7	29.5	9.4	0.7	199.0
7 Lawrence Berkeley Lab	103.6 ^b	16.5 ^b	17.6 ^b	5.5 ^b	174.6
8 Fermi National Accelerator Lab	151.3	0	0	0	151.3
9 Plasma Physics Lab	131.7	0	0	0	131.7
10 Stanford Linear Accelerator Center	79.7	0	0	0	79.7
All others	70.2	3.3	45.8	2.4	129.1
TOTAL, ALL FEDERALLY FUNDED R&D CENTERS	\$1429.8	\$1312.4	\$202.4	\$434.3	\$3529.1

Note: Data for university-administered, federally funded R&D centers. ^a Includes life sciences and other sciences not listed separately. ^b Estimated. Source: National Science Foundation

DEGREES IN CHEMICAL ENGINEERING

1966	2848	994	354
1967	2869	949	305
1968	3211	1156	367
1969	3557	1136	409
1970	3720	1045	438
1971	3615	1100	406
1972	3663	1154	394
1973	3636	1051	397
1974	3454	1045	400
1975	3142	990	346
1976	3203	1031	308
1977	3581	1086	291
1978	4615	1237	259
1979	5655	1149	304
1980	6383	1271	284
1981	6527	1267	300
1982	6740	1285	311
1983	7145	1304	319
1984	7475	1514	330
1985	7146	1544	418

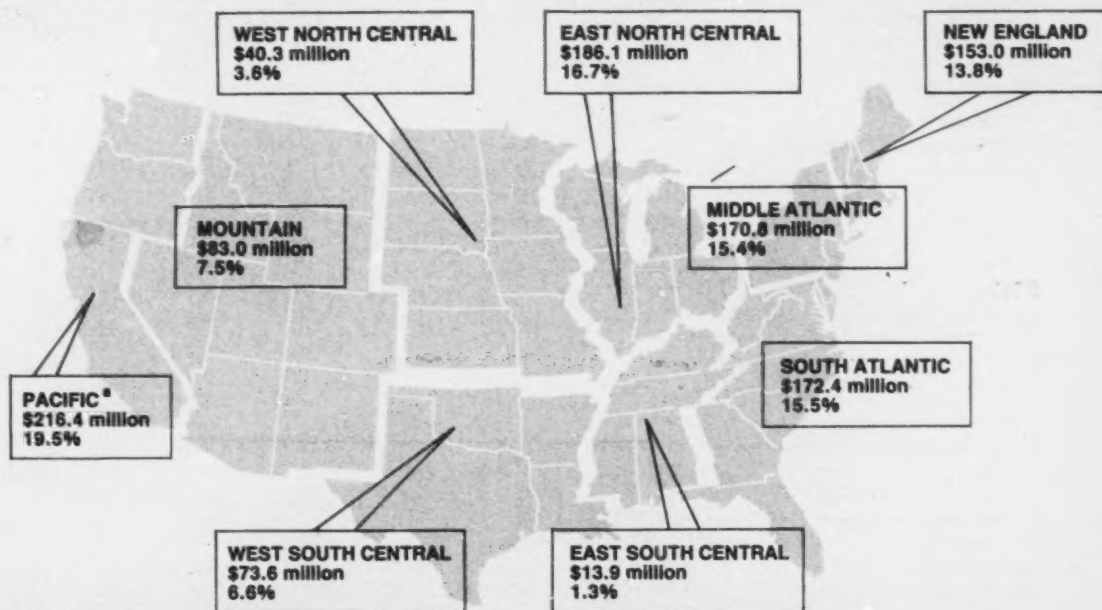
^a Excludes biochemistry and geochemistry. Source: National Center for Education Statistics

SCHOOLS SPENDING MOST ON CHEMICAL R&D: More than 20 spent at least \$5 million in 1985

Rank 1985	Rank 1984		1985		1984	1983	1982	1981	1980	Annual change	
			Total spending (\$ thousands)	% federal funds						1984-85	1980-85
1	1	Massachusetts Inst. of Technology	\$ 13,221	94%	\$ 11,741	\$ 8,914	\$ 9,792	\$ 8,222	\$ 6,764	13%	14%
2	3	U of California, Berkeley	10,804	92	7,850	7,945	6,283	6,553	6,022	38	12
3	2	Harvard U	8,663	76	8,327 ^a	6,898 ^a	5,512 ^a	6,123 ^a	4,797 ^a	4	13
4	5	Stanford U	8,354	85	6,809	6,375	6,116	5,564	4,788	23	12
5	6	Cornell U	7,962	79	6,710	5,717 ^a	6,239 ^a	4,615	3,808	19	16
6	8	California Inst. of Technology	7,605	92	6,446	6,994	6,136	6,901	6,328	18	4
7	12	U of Wisconsin, Madison	7,350	70	6,076	5,310	4,567	4,122	3,976	21	13
8	9	U of Maryland, College Park	7,289	46	6,324	6,333 ^a	4,718 ^a	3,109	2,766	15	21
9	4	U of California, Los Angeles	7,243	93	7,219	5,496	5,187	4,420	4,159	0	12
10	10	U of Illinois, Urbana	7,079	76	6,284	5,886	6,422	5,239	4,261	13	11
		Total, first 10 institutions	85,570	82%	73,786	65,868	60,572	54,871	47,669	16%	12%
11	16	Pennsylvania State U	6,509	90	5,124	4,729	3,564	3,413	2,973	27	17
12	26	U of Colorado	6,360	85	4,134	3,302	3,492	4,047	3,332	54	14
13	11	U of Massachusetts, Amherst	6,291	63	6,137	5,162	4,364	3,230	1,889	3	27
14	13	U of Chicago	6,267	91	5,735	4,798 ^a	4,396	4,139 ^a	3,958 ^a	10	10
15	15	Purdue U	6,018	90	5,443	4,542	4,459	4,600	3,596	11	11
16	19	Texas A&M U	5,896	71	4,610	4,963	4,521	4,069	4,097	28	8
17	14	Indiana U	5,820	84	5,642	5,551	5,341	3,637	3,147	3	13
18	17	U of Notre Dame	5,549	92	4,760	4,022	4,020	3,655	3,457	17	10
19	27	Ohio State U	5,422	71	4,104	3,739	2,907	3,227	2,654	32	15
20	18	Columbia U, main division	5,188	87	4,662	4,281	4,700	3,564	4,437	11	3
		Total, first 20 institutions	144,910	82%	124,137	110,957	102,736	92,652	81,209	17%	12%
21	25	Yale U	5,096	90	4,134	3,341	2,875	2,781	2,023	23	20
22	20	Northwestern U	5,062	78	4,557	3,413	3,026	2,995	2,367	11	16
23	21	U of Pennsylvania	5,025	88	4,375	4,982	3,068	3,386	3,688	15	6
24	34	U of Utah	4,840	91	3,830	3,638	3,364	3,076	2,811	26	11
25	22	U of California, San Diego	4,642	87	4,355	3,910	3,894	4,430	4,425 ^a	7	1
26	23	U of Oregon, main campus	4,640	85	4,255	3,351	2,971	1,389	1,119	9	33
27	7	U of Texas, Austin	4,588	47	6,639	5,938	4,843	4,779	3,970	-31	3
28	31	U of Pittsburgh	4,580	84	3,965	3,267	2,714	2,039	1,641	16	23
29	29	Johns Hopkins U	4,466	93	4,030	4,592 ^a	4,721	4,066	4,652	11	-1
30	30	U of Florida	4,380	53	4,024	2,347	2,248	2,302	2,283 ^e	9	14
		Total, first 30 institutions	192,229	81%	168,301	149,736	136,460	123,895	110,188	14%	12%
31	28	U of Minnesota	4,167	79	4,067	4,047	4,297	4,260	2,642	2	10
32	36	Princeton U	3,963	78	3,670	3,509	3,062	2,513	2,065	8	14
33	37	U of South Carolina	3,729	75	3,423	2,721	2,483	1,087 ^b	970 ^a	9	31
34	33	Georgia Inst. of Technology	3,684	56	3,846	3,401	3,327	3,660	3,655	-4	0
35	40	State U of New York, Stony Brook	3,481	67	3,084	2,607	2,783	2,691	1,966	13	12
36	38	Lehigh U	3,456	39	3,361	3,664	2,584	1,680	1,066	3	27
37	24	U of Connecticut	3,429	44	4,135	2,720	2,049	1,748	1,300	-17	21
38	44	Virginia Polytechnic Inst. & State U	3,339	59	2,633	2,206	1,740	1,581	1,612	27	16
39	39	Florida State U	3,276	32	3,137	2,500	2,959	3,012	2,791	4	3
40	—	Howard U	3,269	91	3,672	2,336	982	1,406	1,287	-11	20
		Total, first 40 institutions	228,022	79%	203,329	179,447	162,726	147,533	129,542	12%	12%
41	44	Michigan State U	3,222	60	2,869 ^b	2,714	2,493	2,178	1,638	12	14
42	41	U of North Carolina, Chapel Hill	3,201	90	2,945	2,397	2,240	2,016	1,789	9	12
43	32	U of Rochester	3,196	90	3,858	3,167	3,123	2,966	2,089	-17	9
44	—	U of California, Irvine	3,142	97	2,177	1,777	1,661	1,915	1,398	44	18
45	—	U of California, Santa Barbara	3,060	89	2,172	1,902	1,698	1,834	1,434	41	16
46	—	U of Virginia	3,046	71	2,516	2,069	1,778	1,781	1,203	21	20
47	—	Iowa State U	2,988	41	2,239	1,903	1,462	1,272	1,159	33	21
48	—	U of Washington	2,964	68	2,340	2,162	2,276	1,500	1,326	27	17
49	40	Wayne State U	2,093	99	3,071	2,645	2,656	2,261	2,163	-32	-1
50	—	Syracuse U	2,900	52	2,110	2,171	2,868	2,259	764	37	31
		Total, first 50 institutions	\$258,644	78%	\$229,626	\$202,354	\$184,981	\$167,515	\$144,505	13%	12%
		NATIONAL TOTAL	\$414,529	74%	\$371,182	\$336,025	\$309,371	\$285,520	\$244,454	12%	11%

Note: Data for institutional fiscal years. a Estimated. b Imputed. Source: National Science Foundation

East and West Coast schools account for 64% of R&D spending in physical sciences



Key to map: Using the Middle Atlantic states as an example, \$170.8 million, or 15.4%, of all R&D expenditures in the physical sciences by all Ph.D.-granting universities and colleges are made in this geographical area. Note: Data are based on R&D expenditures of \$1.11 billion in the physical sciences during the 1985 fiscal year.
^a Includes Alaska, Hawaii, and outlying areas. Source: National Science Foundation

GRADUATE SCIENCE STUDENTS: Chemistry, biochemistry, chemical engineering total 8%

Thousands	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	Annual change	
												1984-85	1975-85
Physical sciences	29.4	28.4	27.7	26.5	25.8	25.4	24.9	24.7	24.8	24.8	24.5	4%	2%
Chemistry	17.3	16.6	16.5	15.8	15.2	15.1	14.9	14.8	14.6	14.4	14.1	4	2
Physics	11.3	11.0	10.5	10.0	9.9	9.6	9.3	9.2	9.5	9.6	9.6	3	2
Life sciences	93.8	92.5	91.2	90.7	90.9	90.7	87.5	85.9	83.3	77.2	73.6	1	2
Biochemistry	4.7	4.5	4.2	4.1	4.0	4.0	3.9	4.0	3.8	3.7	3.7	4	2
Engineering	91.8	88.3	86.4	78.2	74.4	70.1	67.2	64.3	64.4	62.9	64.6	4	4
Chemical	7.0	7.2	7.4	6.9	6.3	5.9	5.4	5.2	5.1	5.1	4.9	-3	4
Metallurgical & materials	3.8	3.6	3.3	3.0	3.0	2.8	2.7	2.5	2.5	2.3	2.3	6	5
Petroleum	0.8	0.7	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.3	14	10
Environmental sciences	14.3	14.3	14.3	13.8	13.1	12.6	12.6	12.2	12.3	11.7	11.0	0	3
Mathematical and computer sciences	39.0	35.4	33.2	30.3	27.1	25.0	22.7	21.5	21.1	21.7	21.3	7	6
Psychology and social sciences	102.8	104.5	105.4	107.3	108.7	109.7	105.8	101.2	100.6	99.8	98.7	-2	0
TOTAL	371.1	363.5	358.1	346.8	340.0	333.7	320.8	309.8	306.6	298.2	293.8	2%	2%
ANNUAL CHANGE	2%	2%	3%	2%	2%	4%	3%	1%	3%	1%	—		

NOTE: Data for Ph.D.-granting institutions only. Source: National Science Foundation

AUGUST 10, 1987

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8/14/87

CHEMICAL & ENGINEERING

NEWS

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Biotechnology

Agricultural research moving
from lab to field

Page 9

News of the Week

■ **U.S. technology trade with China is impeded by barriers in both U.S. and China, resulting in lower exports and the loss of sales to foreign competitors.** Page 6

■ **U.S. and Japan get ready to negotiate renewal of their science and technology agreement and tackle sensitive issues dealing with national security and commercial relations.** Page 7

■ **Himont, world's largest producer of polypropylene, unveils aggressive plans for future growth.** Page 7

■ **U.S. tightens controls on exports of chemicals that can be used for chemical warfare by extending list of those banned for export to Iran, Iraq, and Syria.** Page 8

■ **Month-long workshop to develop materials for elementary school science teaching draws praise from participants.** Page 8

Cover: Calgene scientist checks plants being regenerated by cell and tissue culture methods. Photo by Penina Meisels, copyright 1986

Letters 4

Concentrates

Business 15

Government 18

Science/Technology 24

The Departments

People 29

Newsclips 44

Business

Emphasis on profitability over sales is key to Monsanto's long-term strategy for pharmaceuticals, crop chemicals, animal sciences, high-value plastics, fibers, and resins. Page 17

Government

White House report recommends use of alternative fuels—methanol, ethanol, MTBE, and compressed natural gas—to combat air pollution effectively and economically. Page 19

Technology

Explosives' shock sensitivity may depend on stability of carbon-carbon bonds in aromatic rings and on hydrogen bonding. Page 25

New micropositional electrical probe can measure contact resistance on a microscopic scale, has superconductivity application. Page 26

Chemical plant safety research is made available by the American Institute of Chemical Engineers. Page 26

ACS Focus

Congressional fellowship program enables participating ACS members to broaden their professional views by working for one year as a special legislative assistant on Capitol Hill. Page 27

ACS News

Unemployment among ACS members last year was lower than reported in C&EN's annual salary survey; Project SEED receives a \$250,000 bequest; and ACS voices support to Congress for two bills. Page 28

News Focus

Agricultural biotechnology products ranging from animal vaccines, to microbial pesticides, to herbicide-resistant plants move toward the marketplace, with the potential to revolutionize the practice of agriculture. Page 9



Member unemployment last year lower than reported

Only about half as many chemists who are members of the American Chemical Society actually were out of work sometime last year as was indicated in C&EN's annual report on the economic status of ACS members (C&EN, June 29, page 33).

Initial data from the survey of ACS members indicated that 9% of chemists had been jobless sometime during 1986, including 8% of the men and 13% of the women. The preliminary survey results also had indicated that 12% of chemists with no more than a B.S. degree, 10% of those with an M.S., and 7% of Ph.D.s had had a spell of unemployment during the year.

A closer look at the survey results, made since C&EN published them, now indicates that this degree of unemployment probably is about twice as high as was actually the case. This year's survey is the first to have asked whether respondents were without work any time during the previous year, rather than just at the time the survey was taken last March. Inconsistencies between answers to that question and others in the survey suggest that several respondents misread the question and reported that they had been unemployed when actually they were working throughout the year. For example, many respondents who reported that they had been unemployed sometime during 1986 also indicated that they have worked for their present employer at least since the beginning of 1986.

Adjusting the data to eliminate these apparently inaccurate responses indicates that only 4% of ACS member chemists, rather than 9%, were without jobs sometime during 1986. For men, the figure also is 4%, but for women it is 8%; 7% of B.S. chemists, 5% of those with an M.S., and 3% of those with a Ph.D. were unemployed sometime during 1986, the revised results show.

Of those chemists who were unemployed at any time in 1986, too, fewer were jobless for more than six months than was suggested by the initial survey results. For example, only 21% of all chemists who were out of work sometime during the year were unemployed for between seven and 12 months (rather than 38%, as reported by C&EN). For men, 23% were unemployed for more than six months (rather than 40%); for women, 16% (rather than 32%). In addition, 18% of B.S. chemists (rather than 32%), 19% of M.S. chemists (rather than 39%), and 25% of Ph.D.s (rather than 43%) were unemployed for more than six months. At the same time, the figures for various groups of chemists who were without a job for six months or less actually are in all cases 20 to 30% higher than previously published in C&EN.

David Kiefer, Washington

Project SEED receives \$250,000 bequest

Project SEED, ACS's career development program for economically disadvantaged high school students, has received a \$250,000 bequest from the estate of Horace H. and Thelma A. Selby.

The ACS Committee on Project SEED plans to decide how to use the funds when it meets during the society's national meeting later this month in New Orleans. A program spokeswoman says, however, that some sort of Selby memorial fund will be created, possibly to support a type of activity not undertaken by Project SEED before.

Long-time contributors to Project SEED, the Selbys both pursued chemically related careers in the San Diego area. Horace Selby, an ACS member since 1928, died in May

1986, and his wife, Thelma, died this past May. The couple had no children. Both were active in community affairs, giving freely of their talent and finances, according to friends.

Horace Selby, born in 1906 and described by a long-time friend as "brilliant," studied chemistry at the University of Wyoming for two years in the mid-1920s but did not obtain a degree. He was general manager for American Agar Co. of San Diego during the early 1940s, when he helped develop a source of agar for the Allies when the then-current supply was shut off by Japan. (Agar is a gelatinous substance extracted from certain algae and used in a variety of products, but primarily as a culture medium for bacteriology.) According to one source, because of Selby's efforts, the company was able to supply 90% of the Allies' agar needs.

Also during World War II, Selby formed his own company to manufacture finely ground prisms for use in the Allied war effort. Selby's prisms found use in optic systems in tanks and airplanes used during the war. The manufacture of prisms, in the basement of his house, continued up to the time of his death.

Thelma Selby, a chemical engineer, worked with her husband at American Agar and shared many of his interests. In addition, she created a sizable estate through her personal skills in financial markets. Among her accomplishments is a cookbook with recipes based on agar.

Ernest Carpenter, Washington

ACS offers support for two bills

In recent weeks the American Chemical Society has informed appropriate members of Congress of its support for two bills. One, H.R. 1905, would provide a mechanism for revitalizing university research facilities. The other, H.R. 1692, would allow an individual a permanent tax exemption for employer-provided educational assistance.

In a letter to Rep. Robert A. Roe (D.-N.J.), chairman of the House

Chemical company earnings
continue to grow vigorously
Page 16

AUGUST 17, 1987

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8/14/87

CHEMICAL & ENGINEERING

NEWS

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ANTARCTIC OZONE

Ambitious mission probes
mysterious hole
Page 7

News of the Week

■ Clinical trials of experimental drug tetrahydroaminoacridine to treat memory loss in Alzheimer's victims are planned by government-industry cooperative project. **Page 4**

■ EPA and Velsicol Chemical reach an agreement that will halt U.S. sales of chlordane, a controversial termiticide suspected of causing cancer. **Page 5**

■ Studies by Defense Science Board and Lawrence Livermore National Laboratory warn against premature development of Strategic Defense Initiative. **Page 5**

■ Chemical stocks keep pace with Dow Jones during its recent record-breaking surge. **Page 6**

Business

Major U.S. chemical firms reported continuing strong growth in second-quarter 1987, however economic slump in agriculture, construction, and auto industry is dampening chemical sales to these markets. **Page 16**

Government

EPA is building a database on extent of indoor radon hazard using surveys of gas concentrations in homes in 17 states, data collected by the states themselves, and epidemiological studies. **Page 22**

Science

Two antibacterial peptides—called magainins by their discoverer, NIH scientist Michael Zasloff—have been isolated from frogs, may have therapeutic applications in humans. **Page 27**

ACS News

Overall, employers pay dues for 34% of all ACS members; ACS and the National Materials Property Data Network will offer databases on properties of materials. **Page 28**

Cover: Erebus glacier, Antarctica. Photo by Robert L. de Zafra, SUNY Stony Brook

Letters 2

Concentrates

Business 14

Government 21

Science/Technology 26

The Department

Newsprints 40

News Focus

Airborne Antarctic mission, which is scheduled to begin this week, will probe the origins of the ozone hole over Antarctica. **Page 7**



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August 17, 1987 C&EN

LETTERS

Lift veil of anonymity

SIR: I enjoyed Joel Tellinghuisen's letter (C&EN, June 1, page 2) suggesting that referees for publications be acknowledged in print, and suggest that the notion be taken a step further—that referee comment forms for grant proposals be returned to the submitter with signatures and addresses. Too often it is painfully obvious that proposals that are the result of weeks of hard work are not read in their entirety, are not read by referees with the proper expertise, or have been read by people so lacking in sound judgment that it is unclear how they were selected for the task.

The tales of woe are not only my own. A friend at another small college that had sought an instructional nuclear magnetic resonance spectrometer told me their proposal was rejected because the investigator's expertise to run the equipment was questioned. A few years ago one of my projects was rated low because of an opinion that television just did not belong in a chemistry classroom, and there was evidence then that not all the reviewers had read the proposal carefully.

This year a modest proposal requesting several pieces of equipment that would receive heavy use by the entire

science division was rejected because it was not innovative enough. A comment on the request for a UV-vis spectrophotometer to replace one quite worn out was, "What new experiments could be performed on this new instrument that can't be done on the old?" The answer is that no experiments can be performed if we have no UV-vis. Likewise, a reviewer commenting on the request for electronic balances to replace some triple-beam balances (never having had top-loading mechanical balances) for general and organic labs was, "Electronic balances should not be used in organic chemistry and actually I do not see their purpose in general chemistry either." I question whether the reviewer has student prep workers preparing solutions using triple-beam balances, as I do. This was stated in the proposal.

Perhaps referees are more careful and less biased when evaluating proposals for basic research. From my experience there is a need for more thorough evaluation by more qualified people. If the veil of anonymity were lifted referees might try a bit harder.

Robert F. Drake

Associate Professor of Chemistry
New College of University of South Florida,
Sarasota

Labeling of periodic table

SIR: Like others, I have been following with great interest the correspondence in this column relating to the labeling of the periodic table. Essentially any labels used in the table should perform two basic functions. They should allow us to unambiguously specify the location of an element in the table—a function that is essentially spatial—and they should impart useful information about the chemistry and/or electronic structures of the elements. An ideal system of labels would combine both of these functions simultaneously. However, the large number of systems that have been proposed and the lack of consensus shown in the correspondence suggest that this goal might be overambitious and that we might consider separating these two logically distinct functions.

Therefore, I propose that all tables use both a separate set of spatial labels and a separate set of chemical/electronic labels. The choice of the spatial labels would be fixed and correspond to a simple numbering of the columns, just as we currently number the rows. Thus we would speak of an element as being in

column three (reserving the word group for various chemical/electronic labels) or of the column 17 elements, or, for complete specification, of the element in column two, row six (i.e., Ba), etc. These labels would be used for indexing and abstracting in all papers and books where the authors do not have a special point to make relative to periodic trends.

The choice of a set of chemical/electronic labels, on the other hand, would be left to personal preference. Any book or paper where the authors feel that their particular choice of labels is essential to the points being made would, in all probability, also be a paper or book in which it would be appropriate to reproduce a periodic table explicitly showing the chemical/electronic labeling system

Correction

• July 27, page 61: Wayne State University's total spending for chemical R&D in 1985 was \$2.903 million, not \$2.093 million. As a result, the % federal funds was 72% and the change from 1984 was -5%.

Chemical stocks surge upward with Dow Jones

The Dow Jones Industrial Average was not the only stock market measure to break through barriers and set new ground last week. C&EN's own index of chemical stocks also leaped into new territory.

Last Monday much of the news focused on the Dow Jones Industrial Average as the index surged past the 2600 level to finish the day at 2635, a 44-point, or 1.7%, gain for the day. At the same time, C&EN's index of chemical stocks broke through the 600 level, to finish the day at 603 (1957 = 100), up 1.3% from Friday's close of 595.

C&EN's chemical stock index is based on the weighted market value of seven companies—American Cyanamid, Dow Chemical, W. R. Grace, Hercules, Monsanto, Rohm & Haas, and Union Carbide.

The good news did not end with Monday, however. On Tuesday, the Dow Jones soared another 45 points to end the trading period at 2680, another 1.7% increase over the previous day's close. And again, C&EN's chemical stocks index followed suit, climbing to 610, again a 1.3% gain from the day before.

By Wednesday, however, the market took a breather as profit takers and programed trading took over and the Dow Jones settled back 11 points, or 0.4%, to 2669.32. Chemical stocks settled down, too, but did not retreat as did the Dow Jones.

Instead, C&EN's index climbed an additional point to 611.

"This looks like another barn-burner year for most chemical firms," says Theodore S. Semegran, chemicals analyst for Shearson Lehman Brothers. He points to very low inventories of commodity chemicals, fibers, and plastics, coupled with high capacity utilization rates in much of the industry as giving chemical companies a further boost in business for the rest of the year. Other positive aspects noted by Semegran include increasing exports and decreasing imports of chemicals and pricing improvements in many chemicals. Further, Semegran says, the business in July was practically as good as it was in June, indicating that there was not the summer slowdown normally seen in the chemical industry.

Other analysts also are pointing to tight supplies, particularly in plastics such as polyethylene and polypropylene, as harbingers of continued earnings improvement through the remainder of 1987, and thus as the reason for the good showing in chemical stock prices.

That chemical stocks did so well in the recent stock market rally is not surprising, considering that in the six months ending Aug. 10, they slightly outperformed the Dow Jones and did better than all of the other major market indexes. During

that period, C&EN's index rose 21.6%. The Standard & Poor's 400 Industrials was closest to this with a 21.4% gain, followed by the Dow Jones with a 20.5% gain and the New York Stock Exchange Industrials with a 20.1% increase. However, gains by the other indexes were lower—the Standard & Poor's 500 at 17.1%, the New York Stock Exchange Composite at 14.7%, the American Stock Exchange Index at 14.5%, the Over-the-Counter Industrials at 13.5%, and the Over-the-Counter Composite at only 9.7%.

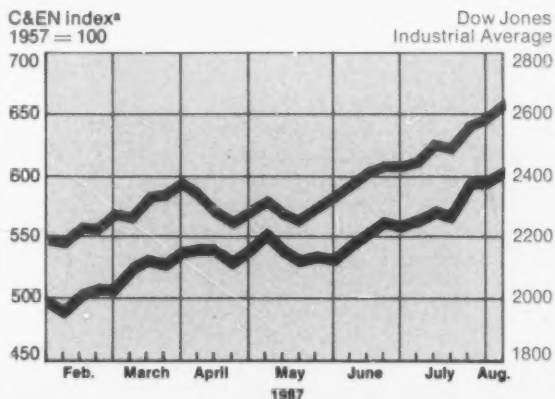
Of the companies comprising C&EN's index, the best performance during the six months before the measure's breaking the 600 level was by W. R. Grace, whose stock price rose 33%. This was followed by Dow Chemical, up 28%; Rohm & Haas, up 23%; American Cyanamid, up 20%; Monsanto, up 16%; Hercules, up 13%; and Union Carbide, up 9%.

The stock market is generally regarded as a leading indicator for company fortunes, and chemical stocks are performing well primarily because of the outlook for earnings in the industry. Through the first six months of this year, earnings for C&EN's sample of 30 chemical companies have risen an average of more than 30% (see page 16) and profit margins for the firms have risen to 6.7%, their highest level in years. And industry analysts say that the earnings outlook for the rest of the year is just as good. □

Chemical stock index slightly outperformed others in past six months

	Aug. 10, 1987	Feb. 6, 1987	% change
Dow Jones Industrial Average	2635.84	2186.87	20.5%
New York Stock Exchange Composite	183.45	159.93	14.7
New York Stock Exchange Industrials	225.96	188.17	20.1
American Stock Exchange Index	362.74	316.73	14.5
Over-the-Counter Composite	446.27	406.91	9.7
Over-the-Counter Industrials	478.42	421.66	13.5
Standard & Poor's 500	328.00	280.04	17.1
Standard & Poor's 400 Industrials	383.89	316.29	21.4
C&EN chemical stock index	603	496	21.6

Chemical stock growth parallels Dow Jones industrials gains



■ C&EN weighted stock price index for American Cyanamid, Dow Chemical, W. R. Grace, Hercules, Monsanto, Rohm & Haas, and Union Carbide.

Chemical Earnings' Strong Growth Continues in Second Quarter

William J. Storck, C&EN New York

Earnings of major U.S. chemical companies grew strongly in this year's second quarter, averaging 30% and continuing a string of year-to-year gains. Strong earnings growth also was reported by major diversified companies that produce chemicals, although total earnings for U.S. oil firms fell.

In addition, average profit margin for chemical firms hit 7.0%, the highest level in years, as earnings continued to increase at a much

greater rate than sales—in the second quarter about three times as fast. However, this is a much smaller multiple than in many recent quarters and may indicate that cost-cutting and productivity improvement measures implemented by chemical companies over the past few years have contributed about all they can. Nevertheless, the cost efficiency steps plus improved capacity utilization in many areas, notably plastics, are still providing plenty of earnings leverage.

In addition to a possible slow-

down of the effects of efficiency moves, there are some further unsettling aspects in many of the major markets for chemicals, notably in agriculture, construction, and automobiles. Agriculture is still in the doldrums after more than five years of farm recession in the U.S. There are signs, however, of relief ahead. The Department of Agriculture recently said that land values in the farm belt may have ended their slide and in some cases have already started to improve. This bit of optimism in the agricultural economy

Chemical industry leaders for the second quarter . . .

Sales			Earnings*			Profitability		
Rank 1987	\$ Millions	Rank 1986		\$ Millions	Rank 1986	Earnings as % of sales		Rank 1986
1 Dow Chemical	\$3408.0	1	Dow Chemical	\$315.0	1	International Flavors	15.5%	2
2 Monsanto	2025.0	2	Monsanto	154.0	2	Ethyl	11.4	3
3 Union Carbide	1658.0	3	American Cyanamid	75.6	4	First Mississippi	10.8	24
4 W. R. Grace	1147.4	5	Union Carbide	69.0	8	Rohm & Haas	10.4	6
5 American Cyanamid	1087.3	4	Rohm & Haas	62.1	5	Betz Laboratories	10.4	5
6 Hercules	688.1	7	Hercules	60.6	3	Loctite	9.9	4
7 Rohm & Haas	597.3	8	Ethyl	47.8	6	Nalco Chemical	9.8	8
8 B. F. Goodrich	551.1	6	Air Products	41.0	7	Dow Chemical	9.2	9
9 National Distillers	550.6	13	B. F. Goodrich	38.3	11	Hercules	8.8	7
10 Air Products	527.8	9	W. R. Grace	36.0	22	Freeport-McMoRan	8.5	1

. . . and for the first six months of 1987

Sales			Earnings*			Profitability		
Rank 1987	\$ Millions	Rank 1986		\$ Millions	Rank 1986	Earnings as % of sales		Rank 1986
1 Dow Chemical	\$6423.0	1	Dow Chemical	\$561.0	1	International Flavors	15.5%	1
2 Monsanto	3891.0	2	Monsanto	292.0	2	Ethyl	11.6	4
3 Union Carbide	3339.0	3	American Cyanamid	137.1	3	Betz Laboratories	10.7	3
4 W. R. Grace	2110.0	5	Union Carbide	135.0	5	Rohm & Haas	10.6	7
5 American Cyanamid	2101.4	4	Rohm & Haas	119.5	6	Loctite	9.8	5
6 Hercules	1352.4	7	Hercules	109.3	4	Nalco Chemical	9.6	6
7 National Distillers	1207.3	12	Ethyl	94.1	7	Dow Chemical	8.7	11
8 Rohm & Haas	1130.4	8	Air Products	82.2	8	Hercules	8.1	8
9 Air Products	1054.9	9	International Flavors	58.6	9	Lubrizol	7.9	13
10 B. F. Goodrich	1036.7	6	National Distillers	50.9	17	Air Products	7.8	12

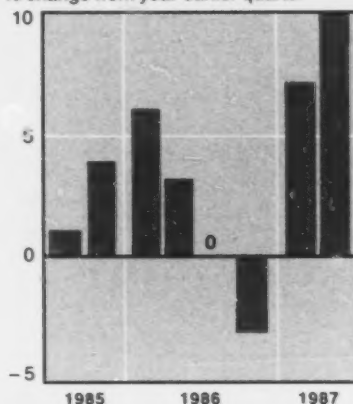
Note: For 30 chemical companies listed on page 18. * After taxes.

Chemical industry second-quarter 1987 results

- Sales increase 10%
- Earnings soar 30%
- Profit margins hit 7%
- Production rises 4.3%
- Prices climb 3.6%

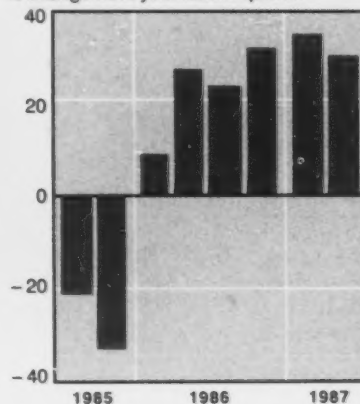
Sales

% change from year-earlier quarter



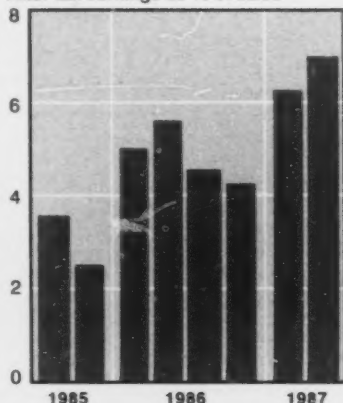
Earnings

% change from year-earlier quarter



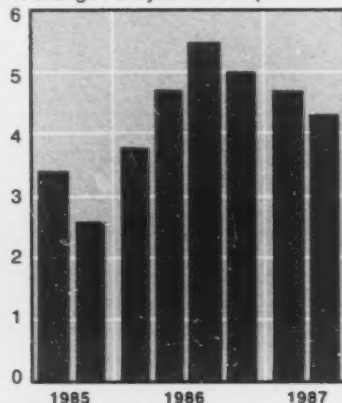
Profit margins

After-tax earnings as % of sales



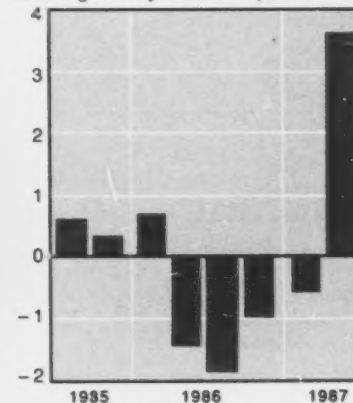
Production

% change from year-earlier quarter



Prices

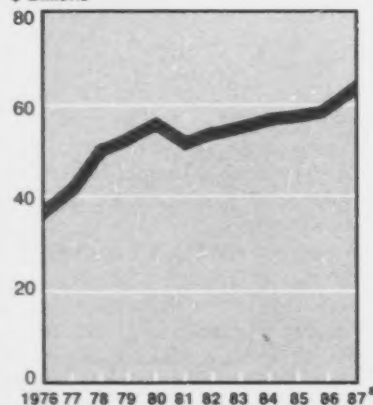
% change from year-earlier quarter



Sales this year will increase about 10%, but earnings will jump 25%, boosting profit margins to 5.7%

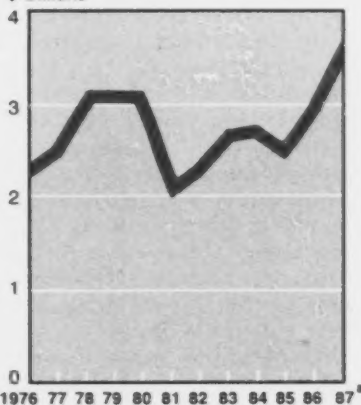
Annual sales

\$ Billions



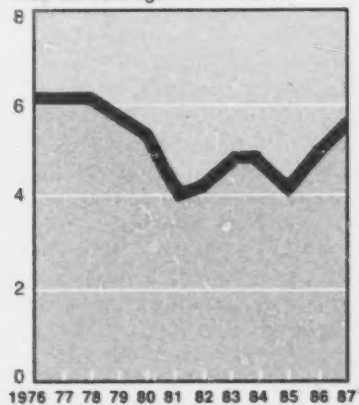
Annual earnings

\$ Billions



Annual profit margins

After-tax earnings as % of sales



Note: All sales, earnings, and profit-margin data are based on combined results of 30 companies listed on page 18. * C&EN estimates.

Earnings and profit margins rise sharply for major chemical companies in second quarter

	SECOND-QUARTER 1987						FIRST-HALF 1987			
	Sales	Earnings ^a	Change from 1986		Profit margin ^b		Sales	Earnings ^a	Change from 1986	
	(\$ millions)		Sales	Earnings	1987	1986	(\$ millions)		Sales	Earnings ^a
Air Products ^c	\$ 527.8	\$ 41.0	8%	5%	7.8%	8.0%	\$ 1,054.9	\$ 82.2	6%	21%
American Cyanamid ^c	1,087.3	75.6	6	34	7.0	5.5	2,101.4	137.1	8	30
Aristech	228.5	16.1	19	50	7.0	5.6	437.2	29.6	13	64
Betz Laboratories	97.5	10.1	12	10	10.4	10.6	186.1	19.8	9	6
Cabot ^c	319.4	14.5	3	1	4.5	4.6	650.6	33.9	0	6
Chemed	98.8	5.3	10	42	5.4	4.1	189.9	9.6	11	34
Crompton & Knowles	64.7	3.6	16	36	5.6	4.8	120.5	6.0	10	25
Dow Chemical ^{c,d}	3,408.0	315.0	20	39	9.2	8.0	6,423.0	561.0	15	40
Ethyl ^c	420.3	47.8	4	-1	11.4	11.9	809.3	94.1	3	13
First Mississippi	90.1	9.7	40	379	10.8	3.1	161.4	12.0	24	191
Freeport-McMoRan	311.9	26.5	88	-10	8.5	17.8	530.7	34.2	63	-12
H. B. Fuller	151.3	6.9	14	32	4.6	4.0	288.7	10.6	15	31
B. F. Goodrich ^c	551.1	38.3	-27	61	6.9	3.1	1,036.7	42.1	-30	1258
W. R. Grace ^c	1,147.4	36.0	25	448	3.1	0.7	2,110.0	47.7	20	260
Hercules ^c	688.1	60.6	0	1	8.8	8.7	1,352.4	109.3	1	4
International Flavors	199.9	31.0	23	29	15.5	14.9	378.8	58.6	22	27
International Minerals ^c	460.5	2.6	4	def	0.6	def	916.5	21.2	7	def
Loctite	96.5	9.5	30	18	9.9	10.9	186.2	18.3	32	45
Lubrizol	267.1	20.6	2	9	7.7	7.3	541.6	42.7	1	17
Monsanto ^c	2,025.0	154.0	8	4	7.6	7.9	3,891.0	292.0	8	10
Nalco Chemical	202.6	19.8	10	28	9.8	8.4	394.2	37.9	9	23
National Distillers ^c	550.6	22.0	53	315	4.0	1.5	1,207.3	50.9	45	122
Olin ^c	485.9	22.3	10	56	4.6	3.2	958.6	46.7	6	21
Pennwalt	311.9	13.7	8	20	4.4	3.9	588.4	26.1	6	3
Petrolite	68.6	4.1	-8	-29	6.0	7.8	132.5	8.1	-12	-30
Reichhold Chemicals	na	na	na	na	na	1.4	na	na	na	na
Rohm & Haas ^c	597.3	62.1	5	11	10.4	9.8	1,130.4	119.5	2	27
Union Carbide ^c	1,658.0	69.0	3	92	4.2	2.2	3,339.0	135.0	4	42
Vista Chemical	160.3	10.7	14	2	6.7	7.5	312.1	22.0	8	13
Witco ^c	356.5	17.6	3	1	4.9	5.0	690.4	32.5	0	3
Total 15 larger companies ^d	\$14,283.1	\$ 978.4	9%	32%	6.9%	5.7%	\$27,671.5	\$1805.2	7%	34%
Total 14 smaller companies ^d	\$ 2,349.6	\$ 187.7	19%	19%	8.0%	8.0%	\$ 4,448.5	\$ 335.3	14%	19%
GRAND TOTAL ^d	\$16,632.7	\$1166.1	10%	30%	7.0%	6.0%	\$32,119.9	\$2140.5	8%	31%

^a Earnings from continuing operations, excluding major nonrecurring and extraordinary items. ^b Earnings as a percentage of sales. ^c One of the 15 largest companies. ^d Averages for 12-month running data do not include Dow, where figures include a major nonrecurring item, and Aristech, Vista, and Reichhold, for which not all figures are available. **def** = deficit. **na** = not available.

could foreshadow an increase in economic activity. If that comes about, it could benefit pesticide producers quickly, but it could be a long time before fertilizer makers see much help as they struggle to raise capacity use to more respectable levels.

Construction activity has slowed recently, especially in the residential area. New housing starts (seasonally adjusted) have fallen in each of the past five months, according to the Department of Commerce.

Perhaps more chilling is the automobile industry. Domestic auto makers are entering the new model year with large inventories of unsold 1987 model-year cars. These inventories exceed more than two

months' supply in some cases and may put a damper on chemical sales to the auto industry through the rest of this year. Further, the big inventories of unsold autos indicate that U.S. makers were unable to take much advantage of the declining value of the dollar against the Japanese yen in their battle against imports. Further, Korean auto makers were able to maintain their prices in relation to American autos as the Korean currency fell along with the dollar.

In spite of the drag of these markets on overall chemical activities, U.S. chemical shipments in the second quarter increased almost 8% on a seasonally adjusted basis from the

same period a year ago. However, production of chemicals and allied products, as reported by the Federal Reserve Board, increased just 4.3% as chemical producers cut inventories going into the normally lackluster third quarter. The 4.3% increase is the lowest since first-quarter 1986, when chemical output rose just 3.8%.

Some of the best news of the quarter was in chemical pricing, which also did a lot to improve earnings leverage in the three-month period. According to Labor Department figures, prices of chemicals and allied products rose 3.6% from last year's second quarter. This ends a string of falling year-to-year price

FIRST-HALF 1987		12-MONTH RUNNING DATA			
Profit margin ^b		Change from 1986		Profit margin ^b	
1987	1986	Sales	Earnings	1987	1986
7.8%	6.8%	7%	7%	7.4%	7.4%
6.5	5.4	8	37	6.0	4.7
6.8	4.7	na	na	na	na
10.7	10.9	5	-1	10.1	10.8
5.2	4.9	-7	1	5.2	4.8
5.0	4.2	1	-1	4.7	4.8
5.0	4.4	-3	17	4.3	3.6
8.7	7.2	5	362	7.5	1.7
11.6	10.7	4	24	11.6	9.7
7.4	3.2	4	72	4.3	2.6
6.4	11.9	29	-15	7.2	11.0
3.7	3.2	16	33	3.8	3.3
4.1	0.2	-32	def	3.3	def
2.3	0.8	11	-56	0.7	1.7
8.1	7.9	2	23	7.9	6.6
15.5	14.9	23	24	14.2	14.1
2.3	def	16	def	0.3	def
9.8	9.0	27	32	9.1	8.7
7.9	6.8	4	23	7.5	6.4
7.5	7.4	1	38	4.6	3.3
9.6	8.5	7	2	8.6	9.1
4.2	2.8	-3	36	4.0	2.8
4.9	4.3	3	9	3.3	3.2
4.4	4.6	7	230	4.6	1.5
6.1	7.7	-14	-31	5.3	6.7
na	1.0	na	na	na	def
10.6	8.5	2	25	9.2	7.5
4.0	3.0	2	47	2.9	2.0
7.0	6.7	na	na	na	na
4.7	4.6	-4	3	4.8	4.5
6.5%	5.2%	0%	31%	4.6%	3.6%
7.5%	7.2%	10%	17%	7.2%	6.8%
6.7%	5.5%	2%	28%	5.0%	4.0%

comparisons that lasted for the four previous quarters.

All these factors translated into higher earnings and sales for the chemical industry. For 29 of the 30 major chemical companies surveyed by C&EN (Reichhold Chemicals had not reported by press time), combined earnings increased 30% from last year's second quarter to a total of \$1.17 billion. Composite sales increased 10% to \$16.6 billion. As a result, the average profit margin (earnings as a percentage of sales) for the 29 firms increased to 7.0% from 6.0% in second-quarter 1986 and 6.2% in this year's first quarter.

The larger companies improved their earnings much more than did

the smaller firms. For the 15 larger chemical companies surveyed, earnings rose an average of 32% (compared with the same 15 firms' earnings in last year's second quarter) to a combined total of \$978 million. Sales for these firms increased 9% to \$14.3 billion. Their combined profit margin increased to 6.9% from 5.7% in last year's second quarter.

For the 14 smaller firms, earnings increased an average of 19% to a combined total of \$188 million, and sales rose an equal amount to \$2.35 billion. Since earnings and sales both rose 19%, average profit margin remained at 8.0%. The higher figure indicates higher profitability of the smaller firms over the larger ones.

In comparing figures for this year's first half, the pattern was much the same as in the second quarter. Combined first-half earnings for the 29 chemical companies increased 31% from first-half 1986 to a total of \$2.14 billion. Combined sales rose 8% to a total of \$32.1 billion. Average profit margin for the group increased to 6.7% from 5.5% during the first half of 1986.

For the 15 larger firms of the group, combined earnings advanced 34% to a total of \$1.81 billion on a 7% sales increase to \$27.7 billion. Profit margins for the group increased to an average of 6.5% from 5.2% in first-half 1986.

For the 14 smaller companies, which are oriented more toward value-added products, earnings grew an average of 19% to a combined \$335 million, and sales increased 14% to a total of \$4.45 billion. Profit margins for the group averaged 7.5%, up from 7.2% in first-half 1986.

Plastics were important contributors to higher earnings at many of the companies. For instance, Dow Chemical executive vice president Robert M. Keil says: "Strong de-

Ground rules for C&EN earnings analysis

C&EN's quarterly report on financial performance of the U.S. chemical industry contains data from the 30 largest U.S. basic chemical companies and from 29 oil and diversified companies, each with more than \$200 million in annual chemical sales.

To be included in the table of basic chemical producers, a company must have at least 50% of its sales in chemicals. That is why Du Pont, for example, is included in the table of diversified manufacturers.

In referring to chemical sales, C&EN means those chemicals whose molecular composition has been changed in the course of manufacture. Hence, chemical sales include those of traditional categories of basic petrochemicals and inorganics, organic intermediates and inorganic compounds, polymers such as plastics and fibers, agricultural chemicals, and specialty derivatives.

In listing earnings, the survey gives after-tax income for continuing operations before nonrecurring items and extraordinary charges. Foreign currency translations are included.

mand for basic chemicals and plastics continued in the second quarter as world economies maintained a moderate but sustained rate of growth. Polyethylene and Styron polystyrene resins were major contributors among basic plastics."

The importance of plastics growth is reflected in B. F. Goodrich's results. Sales of polyvinyl chloride and intermediates for the second quarter increased 19% over the year-earlier period to \$267 million. However, operating income from this division was up 69% in the same period to \$35.4 million.

Agriculture, still generally depressed in the U.S. economy, provided some mixed results among the companies. For instance, American Cyanamid's earnings report states that the "agricultural group registered significantly higher operating earnings as a result of dramatically higher worldwide sales of crop protection, vegetative, and pest control chemicals."

However, for Monsanto, in spite

Earnings were down at many oil firms, but up at diversified companies

	Chemical sales as % of total	SECOND-QUARTER 1987								FIRST-HALF 1987													
		Sales		Earnings ^a		Change from 1986		Profit margin ^b		Sales		Earnings ^a		Change from 1986		Profit margin ^b							
		(\$ millions)				Sales		Earnings		1987		1986		(\$ millions)		Sales		Earnings		1987		1986	
OIL AND GAS COMPANIES																							
American Petrofina	23%	\$	610.4	\$	28.7	30%	547%	4.7%	0.9%	\$	1,149.9	\$	48.5	18%	def	4.2%	def						
Amoco	15		5,629.0		311.0	13	31	5.5	4.8		10,824.0		571.0	-1	0%	5.3	5.2%						
Ashland	20		1,900.0		40.0	6	-51	2.1	4.6		3,500.0		32.0	-3	-74	0.9	3.4						
Atlantic Richfield	33		4,103.0		330.0	16	120	8.0	4.2		7,847.0		569.0	0	27	7.3	5.7						
Chevron	9		7,300.0		194.0	9	-32	2.7	4.3		14,100.0		344.0	-8	-45	2.4	4.1						
Exxon	8		20,162.0		1150.0	12	3	5.7	6.2		39,597.0		2227.0	-2	-46	5.6	10.2						
Kerr-McGee	14		726.4		27.3	16	757	3.8	0.5		1,273.2		47.5	-5	88	3.7	1.9						
Mobil	4		13,529.0		304.0	11	-48	2.2	4.8		26,282.0		556.0	1	-46	2.1	3.9						
Occidental Petroleum	13		4,328.0		59.0	13	51	1.4	1.0		8,485.0		136.0	14	20	1.6	1.5						
Phillips Petroleum	17		2,643.0		3.0	13	def	0.1	def		5,182.0		-29.0	-5	def	def	1.9						
Shell Oil	20		5,487.0		266.0	24	21	4.8	4.9		10,269.0		374.0	9	-24	3.6	5.3						
Sun Co.	3		2,380.0		90.0	-4	-10	3.8	4.0		4,610.0		128.0	-21	-48	2.8	4.2						
Texaco	4		8,500.0		240.0	8	0	2.8	3.0		17,000.0		358.0	-3	-30	2.1	2.9						
DIVERSIFIED COMPANIES																							
Allied-Signal	24		2,846.0		69.0	15	-46	2.4	5.2		5,483.0		213.0	11	-29	3.9	6.1						
Borden	33		1,601.7		62.7	29	21	3.9	4.2		3,030.2		106.7	28	20	3.5	3.7						
Du Pont	44		7,841.0		486.0	13	7	6.2	6.6		14,942.0		877.0	6	2	5.9	6.1						
Eastman Kodak	21		3,210.0		313.9	19	90	9.8	6.2		5,860.0		539.9	16	118	9.2	4.9						
Eli Lilly	19		1,017.6		150.3	16	20	14.8	14.3		2,076.6		355.5	11	19	17.1	16.0						
Engelhard	29		600.9		18.0	22	17	3.0	3.1		1,140.0		31.6	12	18	2.8	2.6						
FMC	47		828.5		133.6	3	172	16.1	6.1		1,552.8		158.9	0	112	10.2	4.8						
GAF	51		214.2		29.7	8	34	13.9	11.2		405.3		50.2	8	35	12.4	9.9						
KaiserTech ^c	12		584.2		-359.1	5	def	def	def		1,121.5		-390.2	3	def	def	def						
Koppers	42		389.1		24.0	5	35	6.2	4.8		660.8		21.0	5	22	3.2	2.7						
3M	15		2,381.0		240.0	9	21	10.1	9.1		4,588.0		453.0	8	20	9.9	8.9						
Merck	9		1,249.3		235.1	24	36	18.8	17.2		2,360.4		436.3	23	32	18.5	17.2						
Morton-Thiokol	33		557.9		36.4	14	21	6.5	6.1		1,077.7		72.6	7	10	6.7	6.6						
PPG Industries	18		1,330.0		102.4	10	12	7.7	7.6		2,590.0		189.3	10	18	7.3	6.9						
Tyler	40		277.6		5.2	12	21	1.9	1.7		533.7		6.2	12	20	1.2	1.1						
Vulcan Materials	27		284.9		38.7	11	18	13.6	12.8		497.7		50.1	9	23	10.1	8.9						

a From continuing operations excluding major nonrecurring and extraordinary items. b Earnings as a percentage of sales. c Includes nonrecurring item. def = deficit.

of a 3% increase in sales of crop chemicals to \$372 million, operating income from these chemicals fell almost 5% to \$147 million.

Overseas business helped some companies. For instance, of Rohm & Haas' 11% earnings gain, chairman Vincent L. Gregory Jr. says: "The earnings improvement in our ongoing operations reflects the sharp gains posted in the businesses outside the U.S. The European and Pacific regions benefited from higher sales volume, better currency relationships, and a lower tax rate. In the North American region, earnings were lower in the specialty chemical segments, with the exception of plastics."

Du Pont, the largest U.S. chemi-

cal producer, cited an 8% rise in overseas sales volume and 11% growth in domestic volume of chemicals and specialty products. Average selling prices, according to Du Pont, increased 4% over the same period last year.

In addition to benefiting the companies primarily involved in chemical production, chemical operations came to the aid of oil companies, which found themselves suffering in the second quarter because of low margins in their product operations. At seven of the oil firms surveyed that also report net income from chemical operations, lower raw material prices and higher demand for petrochemicals pushed up earnings in the second quarter.

The seven firms—Amoco, Atlantic Richfield, Chevron, Exxon, Mobil, Shell, and Texaco—registered a combined earnings increase of 71% for the second quarter compared with the same quarter last year to \$659 million.

Mobil registered the largest increase among the seven; its net income from chemical operations soared 134% to \$75 million. Earnings from chemicals also more than doubled at Chevron, whose net income rose 110% to \$65 million. The smallest increase was a still healthy jump of 33% at Shell, whose chemical earnings totaled \$101 million. The other increases were Exxon 83%, Atlantic Richfield 71%, Texaco 58%, and Amoco 49%. □

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NEWS

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PLASTICS

Output will set records in 1987
Page 27

William Graham: What it's like
to be Presidential Palace Advisor
Page 14

News of the Week

■ **First human testing in the U.S. of a potential AIDS vaccine to begin by October has been approved by the Food & Drug Administration.** Page 6

■ **Ban on plastic packaging for food that is principally targeted at polystyrene "clam shell" packages used by fast food restaurants is being considered by New York's Suffolk County.** Page 7

■ **National Academy of Sciences says the rigid and strict control of biotechnology products is not justified.** Page 7

■ **Unauthorized field tests of a genetically altered microorganism—aimed at combating Dutch elm disease—by Montana State University researcher draw widespread criticism.** Page 8

Business

Canadian chemical industry earnings for second-quarter 1987 register strong increase, even though sales rose only slightly, outpacing the all-industry average. Page 11

A \$200 million investment plan for engineering thermoplastics, which will involve major production facilities for three families of polymers, has been announced by Dow Europe's plastics group. Page 12

Government

Presidential science adviser William Graham discusses broader context, especially national security concerns, of science and technology issues such as competitiveness and superconductivity. Page 14

Science

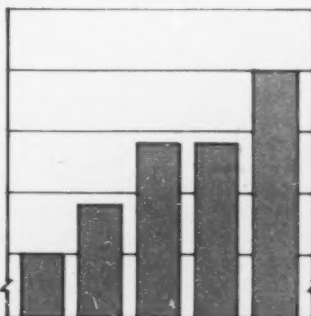
Advances in Fourier-transform techniques have greatly improved the sensitivity and resolution of microwave spectroscopy, enabling scientists to study properties of single molecules and complexes. Page 21

Technology

Planned guidelines for clinical lab workers will reduce risks from frequent exposure to samples from carriers of AIDS and other infectious diseases. Page 25

Cover: Strands of high-gloss ABS resin enter cooling bath at Dow Chemical's Midland, Mich., facility

Letters	4
Concentrates	
Business	9
Government	13
Science/Technology	18
The Departments	
New Products	54
ACS News	66
Newscripts	88



Product Report

The plastics industry is in the midst of a banner year as production and demand reach record levels, and profitability will be the best of this decade. Page 27

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LETTERS

Superconductivity

SIR: In your report on the latest media event in the superconductor serial your editor truncated my comments to meaninglessness. C&EN has failed to provide a technically coherent perspective to all the hoopla surrounding the current superconductivity excesses. It has thereby fallen victim, although it is an international journal, to nationalist self-serving propaganda from U.S. agencies.

First, the U.S. is hardly the leading player in this game. Bednorz and Muller in Switzerland, Kitazawa and Tanaka et al. in Japan, Rao in India, and Zhao in China have made the major scientific contributions so far. Indeed the basic scientific strengths in materials chemistry and ceramic processing on which these materials were based are to be found in France and the U.S.S.R. The U.S. is, in fact, singularly weak in this field. Most of the notoriously publicized U.S. work is by physicists doing amateur chemistry. Indeed the relevant U.S. strengths in materials making, e.g., at Du Pont, General Electric, and Westinghouse, are all but ignored because they do not participate in the hype.

Neither does the work abroad have the frenetic quality we have; no rushing to the *New York Times* with half-baked data on disappearing phases. The scientific community surely has some responsibility in trying to stop the worst abuses such as reporting claims to newspapers before submitting to, or having the work accepted in a scientific journal; grossly exaggerated technical claims (as proved by subsequent events) and possible impacts on society, based on the flimsiest of data; and gross failures (which could be interpreted as willful) to refer to previous work from all over the world.

Second, to allow to pass without comment the absurdly simplistic linking by this Administration's leaders of these remarkable scientific developments directly to potential improvements in U.S. competitiveness is inexcusable exaggeration. I cannot imagine any U.S. corporation being able to even mount a serious competition to Kyocera, Toshiba, Matsushita, etc., if full-scale manufacture of major ceramic superconductor objects ever comes about. Wall Street has made it impossible for good U.S. technical corporations to maintain their long-term applied research capabilities on which industries are built. Simply giving more money to U.S. universities for superconductor research will make things worse, not better. We will pro-

duce even more research for others to use. Giving a lot more money will result in sheer waste.

Last, what the nation must be prepared for is that these new technological developments—if and when they actually lead to substantial new products—will almost certainly decrease the U.S. market share of the older technologies that may be replaced. The public really must get over the idea that the U.S. any longer has a comparative advantage in high technology. Our real hope is in the very balanced mix of technologies, which has been destroyed by similar superhype of the new at the expense of the well established. Additional federal money may be better spent in restoring the balance in our technology base rather than smothering dollars over a single already overcrowded field.

What then should the U.S. do? Make a determined effort to stop the hype. Five hundred person-years of research have not raised T_c above the 90 K of Rao, Zhao, and Wu's. It isn't going to be that easy. Every lab working in the field has seen the blips and disappearing superconductivity. Why do newspapers report them? The Penn State BHK theory may even explain some of the disappearances; let's see if the community agrees. There is no evidence as yet that there is any major commercial potential (100 NMR scanners at liquid nitrogen isn't an industry). But do start telling the President, and his agency heads, that if and when it happens, the probability of a U.S. company making reliable electronic ceramic components for the

Corrections

• June 8, page 70: In the Canadian section of the Facts & Figures for the Chemical Industry special report, the data given in the note of currency conversion are for converting \$1.00 Canadian into U.S. dollars, not \$1.00 U.S. into Canadian dollars. The monetary statistics in this section were converted from Canadian dollars to U.S. dollars on the basis of \$1.00 U.S. equals: 1986, \$1.391 Canadian; 1985, \$1.362 Canadian; 1984, \$1.308 Canadian; 1983, \$1.244 Canadian; 1982, \$1.229 Canadian.

• Aug. 10, page 28: C&EN neglected to point out that the inaccuracy in initial results reported for unemployment among ACS members during 1986 from this year's annual salary survey was first called to C&EN's attention by Nelson Marans of Silver Spring, Md.

Profits of Canadian Chemical Firms Surge in Second Quarter

Combined earnings of four major chemical firms increased 30% in the quarter and 37% in the year's first half

Profits in the Canadian chemical industry are merrily multiplying—no doubt faster than anyone dared to expect at the beginning of the year. Although most industrial sectors of the Canadian economy are enjoying a good year as far as earnings are concerned, the country's chemical industry is certainly ahead of the all-industry average.

That, at least, is what one might conclude from the combined, six-month results of the four large, publicly traded Canadian chemical companies tracked by C&EN. These companies are C-I-L, Celanese Canada, Du Pont Canada, and Union Carbide Canada.

The combined earnings of these four Canadian chemical leaders

jumped a hefty 30% in the second quarter from last year's second quarter. And even though that gain paled somewhat beside the 46% profit increase they chalked up in the first quarter, it was enough to give them an overall 37% jump in profits for the first half of the year.

This first-half profit bonanza is not limited to the four major companies. Scattered results indicate that it is widespread throughout the Canadian chemical industry. For instance, the chemicals division of Canadian Occidental reported operating profits up 38% in the first six months of the year. Shell Canada Chemical turned last year's first-half loss of \$10 million (all figures in U.S. currency) into a \$37 million profit this year. And Esso Chemical Canada's first-half profits increased slightly despite a drop in sales.

As usual when profits surge as they have for Canadian chemical companies, a lot of factors have to fall into place at the same time. Demand for most Canadian chemicals has been strong. Prices have firmed.

This is especially true of several plastics products, synthetic fibers, and chlor-alkalis. The one notable weak spot is fertilizer.

In addition, the rationalization and belt-tightening programs that many Canadian chemical firms have undertaken over the past few years are beginning to pay off. These companies really are leaner and meaner.

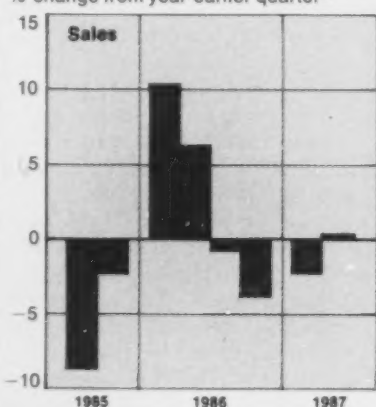
Modestly higher sales volumes, lower raw material costs, and improved productivity are the combination that helped Du Pont Canada chalk up the highest quarterly earnings in the company's history during the second quarter. Net income rose 33% from second-quarter 1986 to \$20.8 million. That increased Du Pont's six-month profit to \$38.4 million, a whopping 57.5% more than in last year's first half.

What makes Du Pont's profit performance remarkable is that it was accomplished with only a meager improvement in sales. Second-quarter and first-half sales were up only 1.2% and 2.3%, respectively.

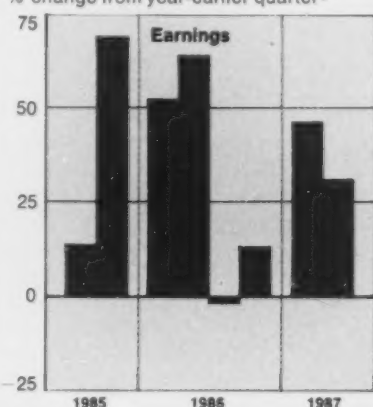
Among other things, J. E. Newall, Du Pont Canada's president, credits

Canadian chemicals sales inch upward, but profits surge

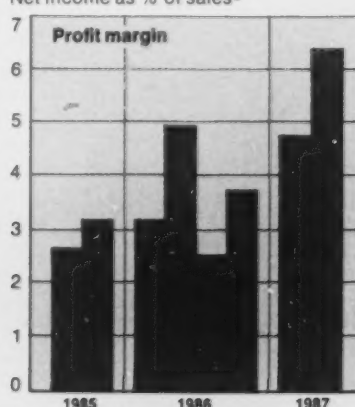
% change from year-earlier quarter^a



% change from year-earlier quarter^a



Net income as % of sales^a



^a Note: Combined results of C-I-L, Celanese Canada, Du Pont Canada, and Union Carbide Canada. ^a Based on Canadian currency.

For Canadian firms, earnings increase despite weak sales

\$ Millions ^a	Net sales	SECOND-QUARTER 1987				Profit margin ^d	
		Change from 1986 ^b	Net income ^c	Change from 1986 ^b		1987	1986
C-I-L	\$291.0	-1.5%	\$14.3	26.7%		4.9%	3.8%
Celanese Canada	65.8	-3.7	5.3	22.8		8.0	6.3
Du Pont Canada	260.1	1.2	20.8	33.3		8.0	6.1
Union Carbide Canada	75.9	8.4	4.2	40.0		5.6	4.3
TOTAL	\$692.8	0.3%	\$44.6	30.4%		6.4%	4.9%
SIX-MONTHS 1987							
C-I-L	\$ 504.6	-5.3%	\$15.7	10.5%		3.1%	2.7%
Celanese Canada	126.2	-3.8	9.7	15.2		7.7	6.4
Du Pont Canada	499.4	2.3	38.4	57.5		7.7	5.0
Union Carbide Canada	147.1	6.2	8.9	47.5		6.0	4.3
TOTAL	\$1277.3	-1.1%	\$72.7	37.1%		5.7%	4.1%

a \$1.00 = 1.330 Canadian dollars (second quarter) and 1.334 Canadian dollars (first half). b Based on Canadian currency. c Based on continuous operations and excluding extraordinary items. d Net income as percentage of sales.

strong fiber demand for his company's performance. And he expects this demand to continue strong throughout the rest of the year. Plastics markets also are strong, with the outlook for specialty packaging films continuing to improve.

Weak spots, Newall says, are the mining, energy, and agricultural sectors of the economy. As a result, demand slackened for explosives, pipe, and herbicides during the second quarter.

Newall also is concerned about some recent price increases in key raw materials and about a softer automotive market. He expects third-quarter results to be down seasonally from the second quarter. But the outlook for the balance of the year remains good.

W. Norman Kissick, chairman of Union Carbide Canada, says the company's profit margins were restrained in the first half "by an inability to increase prices" of many products in line with rising costs. This inability notwithstanding, Carbide Canada bumped its profits upward by 47.5% during the first half, to \$8.9 million, even though sales only managed a 6.2% gain. This profit picture reflects earnings from continuing operations before extraordinary income or expenses.

After taking the market's pulse, Kissick believes that the factors that prevented Carbide Canada from matching price increases with higher costs in the first half are "correcting." This, he says, will have a positive influence on company

performance during the rest of the year.

As far as profits are concerned, Celanese Canada recorded its best second quarter—and best first half—ever this year. Although sales were 3.7% lower than last year, net income rose 22.8% to \$5.3 million in the second quarter. For the half, profit was 15% higher than last year's, even though sales lagged almost 4%.

Paul H. Williams, executive vice president of Celanese Canada, says that, despite lower sales volume for the textile group, income was higher because of lower raw material costs and improved efficiencies. Methanol is still a drag on company performance, but Celanese Canada has placed "sold out" signs on acetic acid, its derivatives, and cigarette filter tow for the rest of 1987.

C-I-L's six-month earnings rose a respectable 10.5% despite a 5.3% decline in sales. One of the most diversified chemical companies in Canada, C-I-L usually is among the industry's profit leaders. But continuing losses in its fertilizer operations are hurting the company this year as they did in 1986.

Still, the company scored solid gains in other areas, such as crop protection chemicals, automotive paints, and chlorine. C-I-L expects these products to perform well for the rest of the year. And an expected reduction in natural gas costs would help improve its fertilizer business.

Earl Anderson, New York

Dow Europe boosts engineering plastics

Officials of Dow Europe's plastics group last week announced a \$200 million investment plan for engineering thermoplastics.

Three families of polymers will be involved—polycarbonates, acrylonitrile-butadiene-styrene (ABS), and chlorinated polyethylene thermoplastic resins. The investment will involve major production facilities for each, with 95,000 metric-tons-per-year combined capacity, and capacity for polycarbonate compounding.

First to start up will be a 20,000 metric-tons-per-year plant for chlorinated polyethylene resins at Stade, West Germany, scheduled to start up next year. According to Dow's estimates, Western European demand for chlorinated polyethylene is growing at about 10% per year.

The company also has begun construction on a plant for ABS capacity of 40,000 metric tons at Terneuzen, the Netherlands, scheduled to begin operating in 1990. Current demand for ABS resins in Europe is about 425,000 metric tons, with demand expected to reach 475,000 metric tons by 1990. Nameplate capacity for ABS in Western Europe has been nearly flat since 1980, Dow says, and producers are currently running at 88 to 92% capacity utilization.

For polycarbonates, a new plant, to be located "somewhere in Northern Europe," will feature Dow's own technology already being used in Freeport, Tex. Start-up is planned for 1990. The attendant polycarbonate compounding plant will be located either at Terneuzen or at Stade and will start up next year.

The manufacturing, or compounding, plant is scheduled to have capacity of 35,000 metric tons per year, but even given recent announcements of polycarbonate expansions by Bayer and General Electric, Dow officials don't see a danger of overcapacity. They are predicting a growth in Europe for polycarbonate of about 8% per year, "a conservative estimate," that probably actually will be nearer 10% per year.

Patricia Layman, London

Plastics In Midst of Banner Year

Bruce F. Greek, C&EN Houston

Profitability in the plastics industry this year will be the best of this decade. Production and demand will increase substantially above 1986. Prices for most plastics will be well over last year's. And most of the individual polymers again will set production records. By all accounts, plastics are in the midst of a banner year.

What's more, a large number of new polymers and variations on existing polymers are coming out of research and development laboratories, which bodes well for potential new growth for the industry.

Among the largest volume plastics, thermoplastics (polyolefins in particular) are in high demand this year. Polyethylene and polypropylene will account for just under half of 1987 production of 39 billion lb of thermoplastics. Counting polyvinyl chloride production, these polymers will make up almost two thirds of thermoplastics output. As a group, production of all of the thermoplastics will increase about 7% this year. An increase also is expected in ther-



Mobil Chemical researcher evaluates new polystyrene for commercial uses

moplastics production next year, but it probably will not be so large as in 1987, because certain thermoplastics have capacity limitations.

The smaller sister group of plastics, thermosets, are more mature and their output will grow more slowly. However, it seems certain that production will top 6 billion lb this year, up almost 3.5% from 1986, excluding polyurethanes. Future growth of thermosets will be lower than that of thermoplastics, probably falling to less than 3% annually next year, and less later on.

By and large, there seem to be few problems in the plastics industry at this time. However, there is some concern that inventories of some of the major-volume plastics

might be building. Rising imports of plastics products and of some resins will reduce what might otherwise have been even larger U.S. production. Collection, disposal, and possible recycling of unwanted plastic products have gained much attention both inside and outside the industry. Limitations on plant capacity to make monomers and polymers are curtailing some of the current optimism for next year and beyond. And capital expenditures needed for new polymerization and fabrication units are large, and it's not certain which companies, if any, are going to shell out those funds for new plants.

Based on estimates through May of this year, 1987 production of plas-

Low-density polyethylene production nears 10 billion lb

This year, U.S. production of all forms of low-density polyethylene (0.94 g per cc or less) will reach 9.5 billion lb, up about 7% from 1986 output of more than 8.9 billion lb. Between 7.0 billion and 7.5 billion lb will be conventional low-density polyethylene (LDPE) and the remaining 2.0 billion to 2.5 billion lb will be the newer linear low-density polyethylene (LLDPE).

Next year, a milestone will be reached for LDPE. U.S. production likely will top 10 billion lb. It will be one

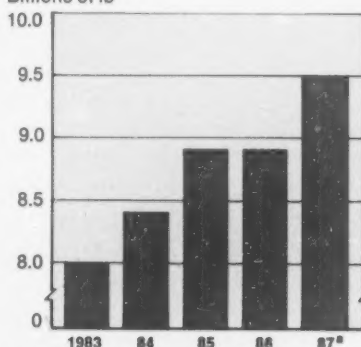
fourth of forecast global output of 40 billion lb in 1988. Because of expected slower economic growth and increased saturation of some of the major polyethylene markets, production is forecast to grow less next year than this year.

Capacity to make LDPE resins currently is adequate. Counting some recent debottlenecking, the U.S. capacity totals close to 11.25 billion lb. About 750 million lb is swing capacity that could be used to make high-density material. An additional 3 billion lb of the remaining 10.5 billion lb of capacity can be used to make either LLDPE or high-density polyethylene.

Sales and captive use of U.S.-produced LDPE and LLDPE are dominated by film manufacture, which will take more than half of the total, or some 5.2 billion lb this year. More than half of the film total goes to various kinds of packaging. The packaging area is split evenly—half for commercial and industrial packaging and half for food packaging and retail bags. Some of the retail bags eventually become competitors for trash bags. Trash bags are considered to be a nonpackaging use of film and (by a slight margin) the largest use of film.

Production

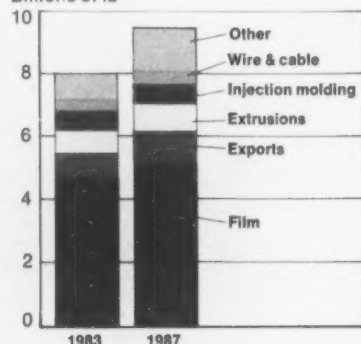
Billions of lb



* C&EN estimate. Source: Committee on Resin Statistics, Society of the Plastics Industry

Consumption

Billions of lb



Source: C&EN estimates

Other significant uses of LDPE and LLDPE are in a host of injection-molded items, in extrusion coatings on paperboard or in paper and foil composites, and in wire and cable coatings. (LDPE's original use in World War II was coating for wire used in early radar.)

Exports of these polyethylenes continue to be high. But imports, especially from Canada, have been growing and are near the level of exports. Future changes in exports and imports likely will be determined by costs of ethylene at producing locations.

tics of all types likely will reach 54.5 billion lb, up more than 3.7 billion lb from 1986, or about 7.3%. This growth rate is well above the average rate for this decade, because production declined 8.3% in 1982 during the last major recession. The current surge in plastics demand began during the second half of 1986 and helped lift output last year 6% overall. Production growth next year likely will slow, because of a need to reduce inventories and the lack of spare capacity to make the large-volume thermoplastics.

Growth may slow even further beyond next year. Chem Systems, a consulting firm headquartered in Tarrytown, N.Y., forecasts in a study for the Society of the Plastics Industry that production in the year 2000 will total 75.5 billion lb. To achieve an increase of 21 billion lb in 13 years, production must grow on average slightly more than 3% annually. The study—"Plastics: A.D.

2000," by Chem Systems—was prepared as part of the 50th anniversary observation of SPI. It expects two recessions to occur before 2000. One recession, considered to be the milder of the two, is forecast to begin in 1989 and end in 1990. The other, arbitrarily set for 1996 to 1998, is expected to be more severe. The two recessions could reduce plastics production as much as did the recession of the early 1980s.

Concerns about recession and the impact of reduced production, sales, and returns are as big in the plastics industry as elsewhere. Wrinkles in the general economy are widely felt because of the sheer size and complexity of the industry. For example, this year sales of unprocessed polymers produced by the industry will exceed \$20 billion. According to a survey made by the SPI in 1985, including subsequent processing, fabrication, and other work by which value is added to

the basic polymers, the total value of sales that year was almost \$140 billion. Capital investments in 1985 were about \$6 billion. The share of the investment in basic polymer-producing facilities was not large that year because of sizable surplus capacity.

Although both production of basic polymers and the volume fabricated into end products are rising, many changes are due in the plastics industry. Consumption patterns change continually. The "Plastics: A.D. 2000" study indicates that packaging will continue to grow in share of consumption of all plastics, reaching 30% of the total by the end of the century, up from 28% in 1985. Consumption of all plastics in electrical and electronic components and by transportation equipment represents smaller uses that are still growing.

All three major markets are expected to increase their share of to-

tal plastics consumption because of demographics. An aging population living in smaller family units will require more convenience and comfort. Packaging, therefore, will shift toward more single-service containers, aesthetically appealing disposables, and aseptic packages. Comfort demands will increase plastics consumed in home entertainment equipment, other appliances, and transportation equipment.

Construction's share of plastics consumption will decline, however, according to the Chem Systems study, largely because the use is growing more slowly than are several others. Nevertheless, construction will take 20% of all plastics consumption in 2000, down from an estimated 22% in 1987. Consumer products' share of total consump-

tion is expected to decline, as is exports' share.

Several end uses of plastics that are holding their share of the total market are classified by SPI as adhesives, inks, and coatings; consumer and institutional products; electrical and electronic; furniture and furnishings; industrial; transportation; and other. Each of those categories, although holding its share of the total market, comprises segments that will grow or decline. Future life styles and the type of services demanded will determine that growth or lack of it.

The category of adhesives, inks, and coatings does not include adhesives used to bind plywood and particle-board wood fibers; those polymers are included in the construction-use category. Many of the

materials included in the adhesives, inks, and coatings category grew in use because they captured markets from other materials. They now dominate certain markets; for instance, polyvinyl acetate has a large share of latex paints, and thus its use will grow little. Other plastics, such as the epoxy resins, are relatively expensive, and that limits growth. New adhesive uses—for example, the replacement of mechanical fasteners—are likely to be the area of largest growth.

Consumer and institutional products include uses of plastics in such areas as toys, housewares, recreational equipment, medical equipment and disposables, and business equipment. Plastics have considerable potential to capture markets in this category from metals, glass, nat-

High-density polyethylene continues to record strong growth

Production of high-density polyethylene (HDPE), whose density is above 0.94 g per cc, is still growing unabated. Output this year may reach 7.7 billion lb, a rise of 7% that will approximate last year's increase. Continuing development of new markets for HDPE is behind this growth.

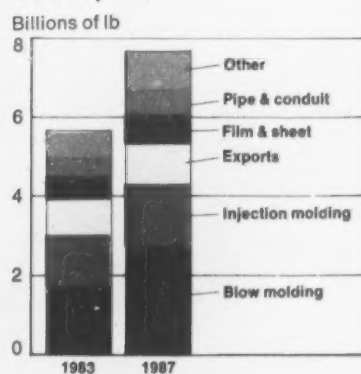
The capability of some producers to shift use of some of their capacity between production of HDPE and linear low-density polyethylene (LLDPE) solves the problem of current limits on conventional HDPE capacity. The newer units designed as dual capacity, for making either kind of polyethylene, total about 3 billion lb. Another

0.75 billion lb of capacity is designated as swing capacity for either HDPE or LLDPE, for it can be quickly shifted between the two products. The dual capacities are generally newer than some 6.5 billion to 7.0 billion lb of capacity initially built to make HDPE and subsequently debottlenecked to the higher estimate, or to possibly more.

Demand for LLDPE also continues to be strong in such end uses as film for a variety of bag applications; as a result, not much of the LLDPE capacity may be available to make HDPE. It is apparent, therefore, that to make the 7.7 billion lb of HDPE forecast for this year, all of the basic capacity, most of the swing capacity, and a small part of the LLDPE capacity must be utilized.

Pressure is put on HDPE capacity predominantly by the container market. A decade ago, the swing began toward blow-molded milk, juice, and noncarbonated drink containers in the 1-gal and 0.5-gal sizes, as well as toward bottles for household bleach, antifreeze, and many other consumer products. More recently, a surge toward motor oil bottles has kept HDPE demand growing, even as growth in other uses has settled down to nearly population growth. Other current, fast-growing uses are in shipping drums and automotive vehicle fuel tanks.

Consumption

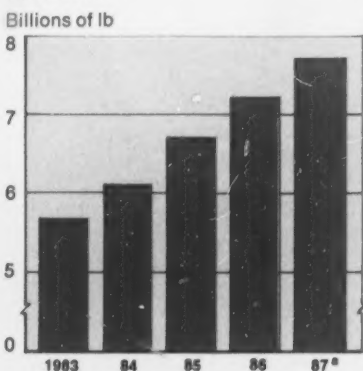


Source: C&EN estimates

In the area of injection-molded HDPE, a host of new industrial items are being developed. Moreover, additional growth is forecast in demand for HDPE open-headed containers, primarily in the 5-gal size. Demand for materials-handling items such as pallets, crates, and trays also is increasing rapidly.

Extrusions of HDPE, mainly film (often blended with LLDPE), go into merchandise bags and many other forms of packaging as well. Film has been successfully challenged by pipe and conduit as the largest extrusion use. Both of these use areas will grow about as fast as will other uses of HDPE.

Production



* C&EN estimate. Source: Committee on Resin Statistics, Society of the Plastics Industry

Capacity limits polypropylene demand growth

Limited capacity to make polypropylene will hold down production growth this year. Polypropylene production will rise to 6.3 billion lb, up more than 8% from 1986, but demand would push production even more if more capacity were available.

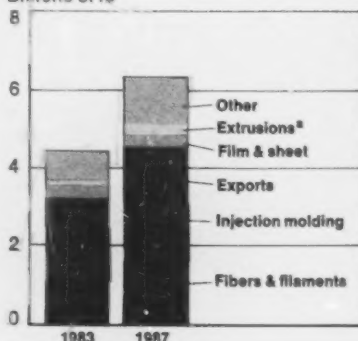
This year began with U.S. polypropylene capacity at about 6.3 billion lb. During the year, several producers have made major additions and debottlenecked operations to add 300 million lb to annual capacity. Total capacity will be about 6.6 billion lb at the end of 1987. Because the additions will be producing for just part of this year, however, capacity will be strained to meet demand. And since demand growth continues to keep pace with capacity growth, the tight supply-demand situation will continue next year even as other major capacity expansions start up.

Additional polypropylene for U.S. markets could be diverted from the substantial exports of the plastic; consumers would merely have to pay a price higher than the export price. Exports in 1987 could reach 1.25 billion lb, possibly 1.5 billion.

The relatively large exports are the result of limited availability of polymer-

Consumption

Billions of lb



* Other than film. Source: C&EN estimates

grade propylene in some Asiatic and Latin American countries. Although no major changes in export demand for polypropylene are expected for the near-term, additions of steam crackers in the Far East eventually could reduce polypropylene exports from the U.S.

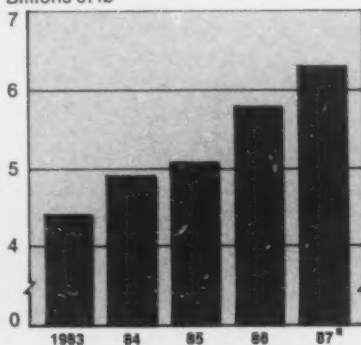
Among major uses of polypropylene, a wide variety of injection-molded items take nearly a third of consumption. One major end use of those items is in transportation, such as in auto components and battery cases. Another is packaging, including many kinds of containers and the caps and lids for various containers made of other plastics. Many other consumer, medical, and appliance items use this plastic. Expected growth rates for polypropylene in these varied uses range from about zero to very high rates for some automotive components.

As a use for polypropylene, fibers and filaments run a close second to injection-molded items. This use as a group is growing more slowly. The most rapidly growing segment of the market is the nonwovens.

Other applications include film, sheet, blow-molded items (largely bottles), and many small-volume products. They will grow about 5% annually.

Production

Billions of lb



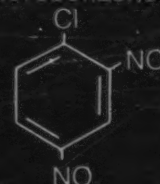
* C&EN estimate. Source: Committee on Resin Statistics, Society of the Plastics Industry

ural and synthetic fibers, and ceramics. Growing interpolymer competition partly handicaps those markets. Changing interests and fads intermittently affect use in toys, housewares, and recreational equipment. In medical markets, high

growth of plastics will continue, as plastics replace glass and metal in both disposable and sterilized items. Disposable plastic-film-based gowns and various other kinds of coverings are replacing fabric items that have to be laundered. These dispos-

SANDOZ INTERMEDIATES

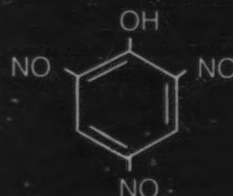
2,4-Dinitrochlorobenzene



DNCB

CAS 97-00-7

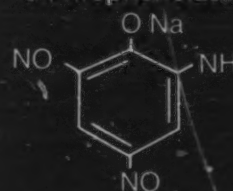
2,4,6-Trinitrophenol



Picric acid

Send spec sheet CAS 88-89-1

Sodium 2-amino-4,6-dinitrophenolate



Sodium picramate

Send spec sheet CAS 831-52-7

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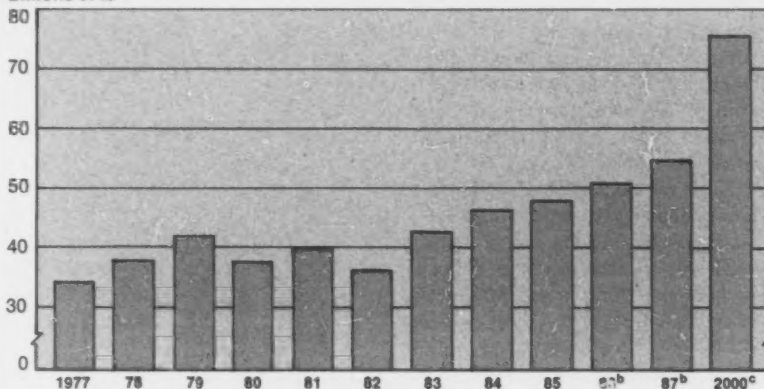
Product Report

ables could become the fastest growing items in the medical market. Cookware for microwave ovens (both disposable and reusable) could be the second fastest growing area. But that growth will be offset by lower use of plastics in toys and recreational equipment, as the population ages and demand for those items falls.

The electrical and electronic devices market is one of the smaller end-use areas of plastics that will have an increase in share of consumption, according to Chem Systems. SPI includes in this group all kinds of appliances, computers, industrial equipment, auxiliary parts, and many other items. Capture of markets by plastics in that category varies widely. From the beginning, cases for some products (computers, for example) were made of plastic. In small household appliances, such as mixers, plastics have become the dominant material, replacing metal in the casings.

Plastics output forecast to grow nearly 40% by year 2000

Billions of lb^a



^a All types, including polyurethanes. ^b C&EN estimate. ^c Chem Systems Inc. estimate for Society of the Plastics Industry. Source: Committee on Resin Statistics, Society of the Plastics Industry

Extensive replacement of metal by plastics in large appliances has yet to occur in the electrical and electronics market. Potential for growth in this market lies in housings made of plastics, whereby as-

sembly could be simplified and much painting eliminated, lowering the final cost of an appliance. Further development and modification of polymers and of fabrication techniques will be necessary if plastics use is to increase rapidly and rise above the 5% of materials now used in appliances.

Furniture and furnishing uses of plastics are dominated by two kinds of polymers—polypropylene and polyurethane. No growth in market share by 2000 is forecast for those uses, partly because of the decline in PVC use in flooring and furniture. In a kind of interpolymer competition, polypropylene fibers in carpet and fabrics have made large inroads into use of PVC. Though much of the shift toward polypropylene has been completed, overall use of plastics in furniture and furnishings is expected to grow, as the number of households increases and as they require more items, and as the population ages and demands easier maintenance of household equipment.

Furniture and furnishings account for more than a third of consumption of polyurethane foams, almost entirely flexible foams. Another sizable share of polyurethanes goes into similar products, such as seating in automobiles and trucks, which is categorized as transportation equipment. The other major use of polyurethanes, in building and construction, is mostly as insulation in roofing and sheathing.

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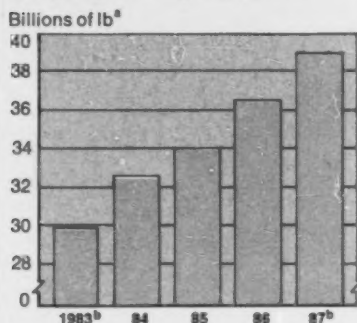
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Thermoplastics production keeps growing unabated



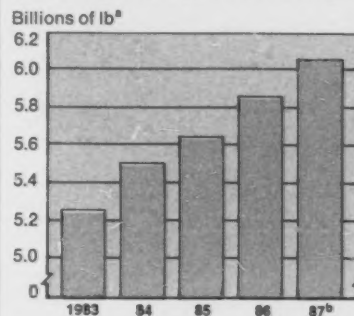
a Acrylonitrile-butadiene-styrene, nylon, polyethylene, polypropylene, polystyrene, polyvinyl chloride, styrene-acrylonitrile, and thermoplastic polyester. b C&EN estimate. Source: Committee on Resin Statistics, Society of the Plastics Industry

The industrial market share of plastics is small and is expected to remain so. Capture of markets from metals has been slow and spotty. Because of the higher performance required, the more expensive engi-

neering resins—phenolics and other thermosets, as well as specialty resins, including the newer blends and alloys—account for much of the consumption in this market.

Use of plastics in transportation occurs mostly in the passenger car and light truck area, which will show slow market share growth despite the potential to capture market from metal. That is because car production will grow slowly in the future, even though Japanese manufacturers are adding to their U.S. operations. Much of the future growth in those areas will occur in exterior body components, because auto makers have gone about as far as they can in using plastics for interior and under-hood parts. Further developmental work, however, is needed before problems in paint technology and in differences in thermal expansion between plastics and metals are overcome. Other transportation equipment uses are in mass-transit vehicles and aero-

Thermosets output is growing slowly but steadily



a Epoxy, melamine, phenolics, unsaturated polyester, and urea. b C&EN estimate. Source: Committee on Resin Statistics, Society of the Plastics Industry

space, both of which are growing in usage of plastics but from small bases.

Another use category includes the large quantities of plastics sold by producers to resellers and compounders. Most of the volume even-

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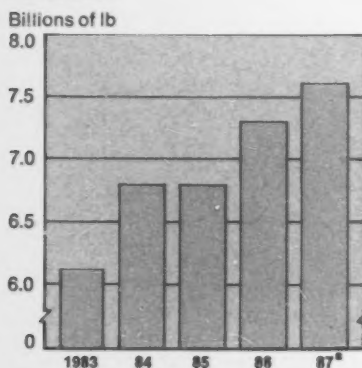
Polyvinyl chloride growth resumes at slow pace

Somewhat slower growth is forecast for polyvinyl chloride production than for other major-volume thermoplastics this year. PVC output will exceed 7.6 billion lb in 1987, up about 5% from last year. Next year's growth rate likely will be about the same.

Current midyear capacity to make PVC by the various polymerization technologies—bulk, emulsion, solution, and suspension—including copolymerization capacity, totaled about 8.8 billion lb. That estimate excludes some units that have been shut down for some time; these units account for less than 500 million lb and aren't likely to be restarted. Because production time is lost when grades are changed and because of technical restrictions posed by stringent emission controls, an annual output of more than 8 billion lb would require plants to be run full out. Nevertheless, debottlenecking of capacity continues as technology improves in catalysts, emission control, and polymerization.

Late last year and early this year, sales and use of PVC rose more rapidly than output of PVC, drawing down inventories. Since then, output has moved closer to sales and use. Consumption may slow this summer as a

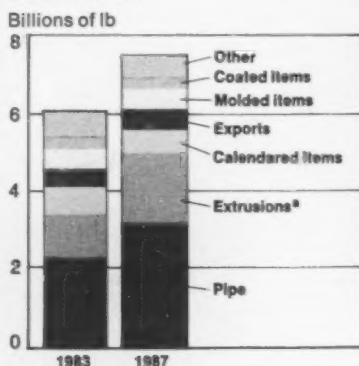
Production



^a C&EN estimate. Source: Committee on Resin Statistics, Society of the Plastics Industry

tually may be included in one or more of the other categories, with some of it as off-specification material sold on the basis of its price and not on its potential performance. SPI's Committee on Resin Statistics is attempting to reduce this

Consumption



^a Other than pipe. Source: C&EN estimates

result of a slowdown in new housing construction.

Construction dominates use of PVC, with extruded pipe and conduit taking nearly half of U.S. consumption. Besides pipe, other construction uses are in such extrusions as siding and gutting. They also include molded items such as pipe fittings, calendered items such as flooring, and coated items such as wall coverings. Wire and cable coverings and fittings take another sizable quantity of PVC into the construction market. Future growth for PVC, in effect, will depend on construction and, to some extent, remodeling.

Other end uses include a host of consumer products ranging from phonograph recordings to toys and garden hose. PVC film and sheet have a continued market in packaging and in transportation equipment. As a group, the nonconstruction uses of PVC are growing at a little above population growth.

PVC demand could increase significantly if imports of fabricated PVC products, mostly consumer goods, are restricted by government regulations. Estimates of the quantity of PVC used in imported items cluster around 1 billion lb annually. These imports are rising faster than domestic demand for PVC.

category to reflect more clearly the consumption patterns for plastics.

The big jump in exports of plastics clearly is over. Although exports may rise for certain polymers—polypropylene and some engineering plastics now entering the commod-



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Polystyrene demand eases and production closes the gap

Sales and captive use of polystyrene outstripped production well into the second quarter of this year, and inventories fell. That demand pressure, along with a brief increase and then decrease in benzene prices, advanced polystyrene prices to well above 50 cents per lb before a summer softening began.

With demand pressure now eased, production is forecast to be about 5 billion lb this year, up 11% from 1986. To reach that level, plant operations will have to be pushed to about 90% of nameplate capacity of 5.6 billion lb. Output and capacity of crystal, impact, and expandable bead forms of polystyrene are included in the estimate.

Output growth has been possible because of a recent round of minor capacity expansions—the first in some time other than debottlenecking. Other expansions expected by 1989 will

total less than 10% of current capacity, which is about the same amount that demand is expected to grow during that time.

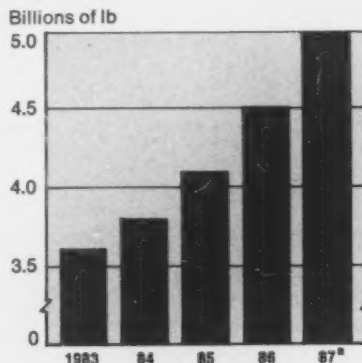
Polystyrene uses are similar to those

of polyethylenes, in that more than half of consumption goes into disposable items, particularly into many kinds of packaging. Other disposables include food serviceware and medical devices.

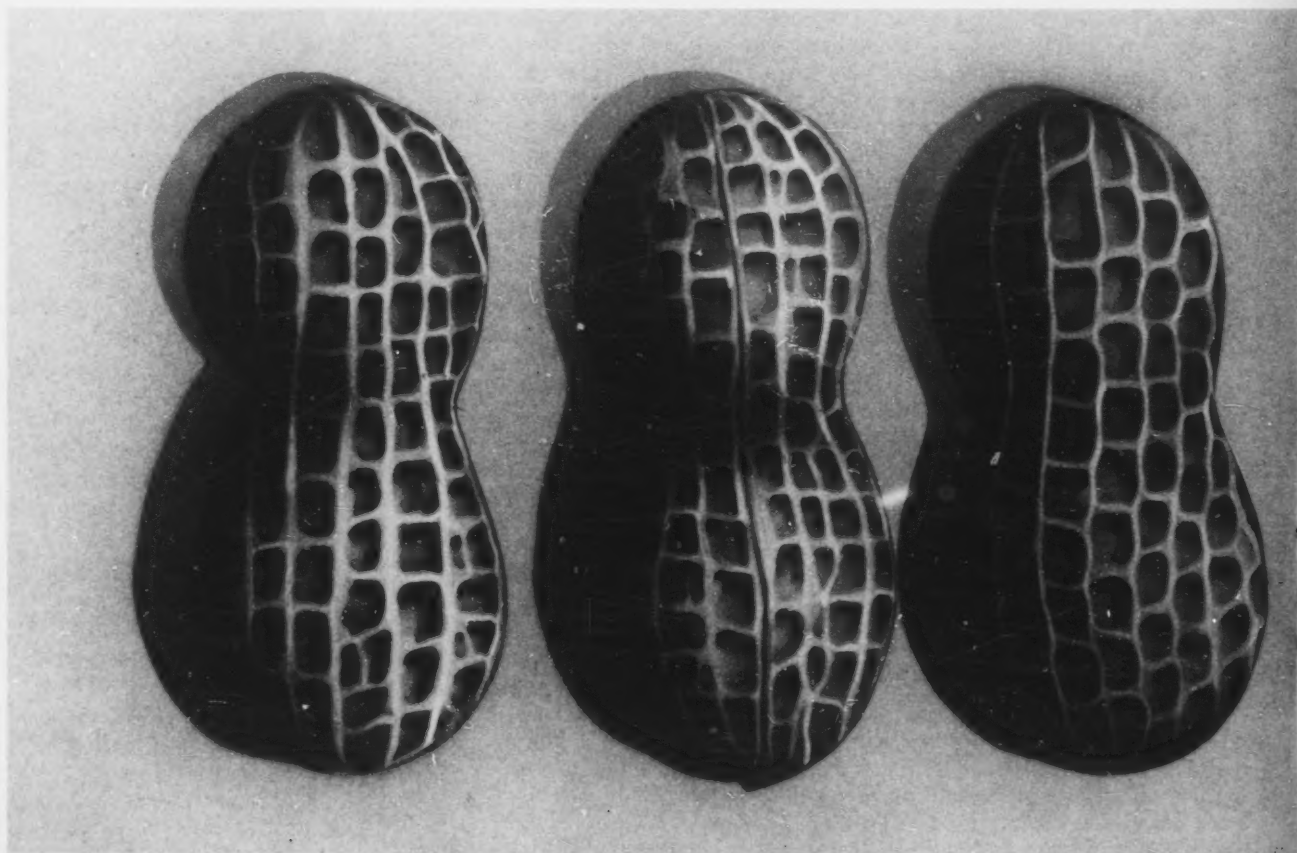
Demand growth for polystyrenes used in disposables barely exceeds population growth. Polystyrene has few markets left in the disposables area that can be captured from nonplastic materials. Part of the disposables market of polystyrene has, in fact, been lost to other plastics that cost less or are easier to fabricate. Thus, although polystyrene demand will surge this year, the growth rate will decrease. However, demand for disposables does not decline much during times of economic recession, and that could help future polystyrene demand, assuming a recession occurs.

Polystyrene resins also go into a

Production



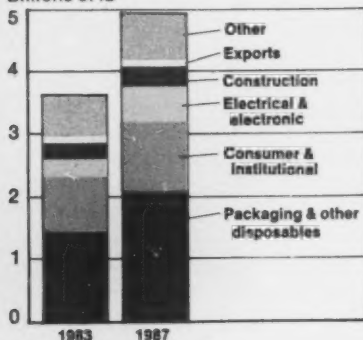
^a C&EN estimate. Source: Committee on Resin Statistics, Society of the Plastics Industry



host of longer lasting consumer and industrial products, including many kinds of housewares, toys, appliances, home and office furniture and furnishings, recreational items, and electrical and electronic parts. Some of those

Consumption

Billions of lb



Source: C&EN estimates

applications will have low growth, especially those facing competition from other plastics. Use in appliances and furniture and furnishings will grow 4 to 5% as polystyrenes are developed to compete with the more costly plastics. Construction use—foamed sheet or board, in particular—will depend mostly on industrial and commercial construction and will grow at rates above that of total construction, as energy conservation efforts continue.

Foamed polystyrene is one of the growth areas of packaging. It is used increasingly in the "clam shell" containers for fast foods, in egg cartons, and in loose-fill and molded packaging. High-impact polystyrene is finding growing use in appliance cabinets, computer parts, and furniture. These applications will help push polystyrene demand growth to about 5% annually.

ity-size classification—the growth in exports will be up much less than will total growth in production. Chem Systems projects exports in 2000 at 5.16 billion lb, up a little more than 1.2 billion lb from 1985 exports. Low growth in exports will result largely from competition in Latin America and Southeast Asia, beginning by 1990.

Imports of both intermediate and finished plastics products, as well as products containing plastic components, have considerable impact on U.S. plastics production. Imports of molded items such as toys, household items, components for appliances and other mechanical goods, and apparel have been growing fast. Film and plastic bags have recently become sizable imports. Imports of cars and electronic equipment bring in large quantities of plastic components. Changes to be made in these imports are difficult to forecast before a trade bill is passed. Even if passed, a trade bill probably

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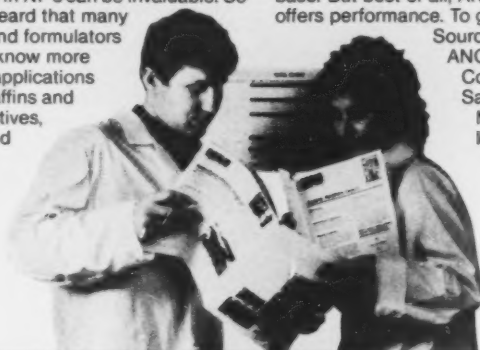
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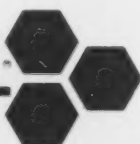
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would merely slow the growth rate of imported fabricated plastic products. Consequently, loss of potential polymer production and subsequent fabrication in the U.S. will continue, diminishing the volume of plastic products that might otherwise be made in the U.S.

Each of the major raw materials used in plastics—ethylene, propylene, and benzene—was given closer attention during the first half of this year, because of the questions about current and future availability. For example, present operating ethylene capacity is being run at about optimum levels. A considerable amount of additional ethylene capacity, shut down because of the recession in the early 1980s and not yet operating again, could be restarted if producers find that the costs of doing so would be covered by returns from the operation of this capacity. Additional ethylene production will result from various debottlenecking programs for currently operating units.

Industry views on when more capacity will be needed vary, depending on the forecasts for growth in plastics demand (and in turn ethylene demand). One scenario suggests that, with about a 6% growth in demand in 1988, currently operating ethylene capacity will supply

Packaging will remain largest use of plastics

	Share of plastics market		
	1970	1985	2000
Packaging	24%	28%	30%
Building & construction	21	22	20
Consumer products	11	8	7
Electrical & electronic	10	6	7
Adhesives, inks, coatings	8	5	5
Furniture & furnishings	7	5	5
Transportation equipment	5	5	6
Industrial	1	1	1
Other	7	12	12
Exports	6	8	7
Production (billions of lb)	19.2	47.8	75.6

Source: Chem Systems Inc. for Society of the Plastics Industry

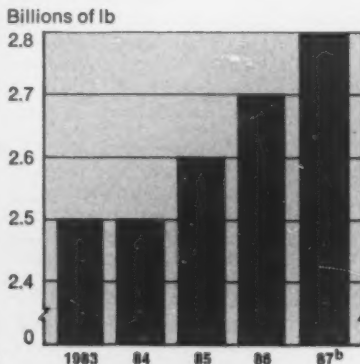
Growth in phenolic resins will remain slow but steady

Historical performance of slow and steady growth again will characterize the various phenolic resins this year. Production growth will remain small because the long-established phenolics are going into few new markets and because existing uses are mature. Nothing short of a major economic downturn could alter that pattern either this year or next. Output of phenolic and other tar acid resins this year will rise about 3% to 2.8 billion lb, on a gross weight basis.

Most phenolic resins are products resulting from reactions of phenol with formaldehyde. Many variations in the final products are offered commercially or used captively to make specialized end products.

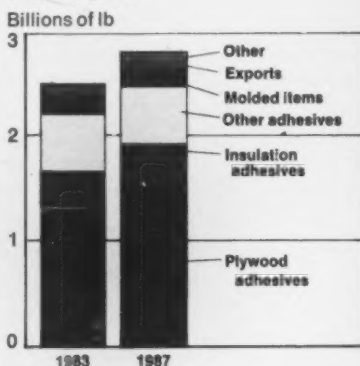
Most of these resins are made in batch operations in large vessels with little auxiliary equipment. Consequently, investment costs are low and the product cost depends heavily on the raw materials costs. The increase in benzene prices during the second quarter, because it affected phenol costs and availability, temporarily upset phenolic resin prices. However, prices now have settled back into the usual highly competitive conditions.

Production*



* Gross weight basis. ^b CAEN estimate.
Source: Committee on Resin Statistics, Society of the Plastics Industry

Consumption



Source: CAEN estimates

Reliable estimates of capacity to make phenolic resins are not available for several reasons. During downturns (for shifting to manufacture of different resins), capacity is lost. As requirements for use change, operating of plant units may be intermittent. And some equipment is used to make resins other than phenolics.

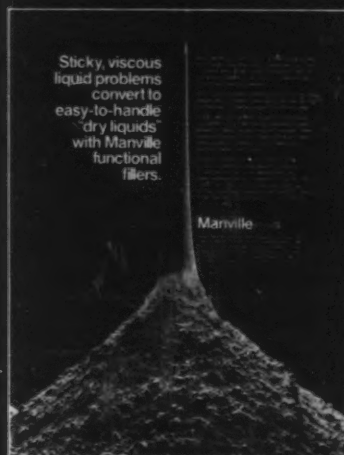
Accurate production estimates also are unavailable. Because of uncertainties in reports of resin production, the Committee on Resin Statistics of the Society of the Plastics Industry shifted its reports to a gross-weight basis in 1981, thereby including the weight of fillers and carriers. Depending on the end use, the actual resin content of the product shipped or used varies from less than 50% to more than 80%.

Most phenolic resins are used as adhesives. Plywood adhesives alone consumed more than half of production. Adhesives for wood fiberboard rank third in consumption after insulation materials such as glass fiber adhesives. Thus, the outlook for these resins depends on construction, which has grown only slowly for some time. Nonadhesive uses are largely in molding compounds for making many different consumer and industrial products. Growth in these uses also has slowed.

all needs next year. Because of additional debottlenecking, restarting part of the shut-down capacity each year, shifting the average feedstock composition, and a slowing of demand during a mild recession in 1989, no additional new capacity

may be needed until 1991, or possibly 1992.

Supply of propylene is partially related to ethylene production as one of the coproducts of steam cracking of hydrocarbons. Because of the demand surge for polypropylene,



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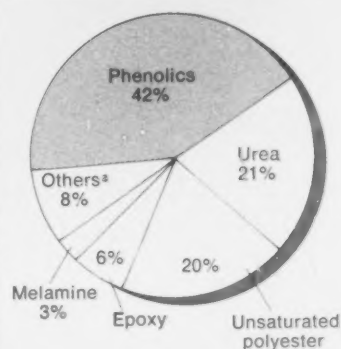
Manville

Product Report

supplies of polymer-grade propylene have become tight, and prices for both it and chemical-grade propylene have increased to levels well above the price for ethylene. That is a reversal of the historical situation in which propylene prices were typically 75% of ethylene prices. The rise in prices for propylene has led to the expected result of drawing sufficient propylene from other sources (such as refineries, where it is made in catalytic cracking units) to meet chemical and polymer demands. Longer term, propylene supplies will be large enough to meet nonrefinery demands, as long as consumers pay a price competitive with the alternative value to refiners.

For the other major raw material for polymers, benzene, more than three quarters of its consumption in chemicals goes to styrene, most of which is polymerized to polystyrene. The increase in benzene prices during the second quarter was large-

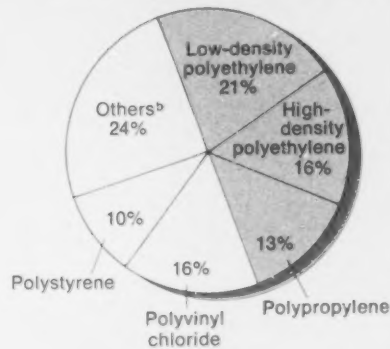
Phenolics dominate thermosets production...



1987 production = 6.05 billion lb

^a Includes alkyds and silicones. ^b Includes acrylonitrile-butadiene-styrene, styrene-acrylonitrile, polyvinyl acetate, and thermoplastic polyester. Source: C&EN estimates

...and polyolefins lead thermoplastics production



1987 production = 39.0 billion lb

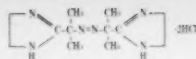
ly a result of marketing events and not the result of large demand growth. As is the case for propylene, plenty of benzene is available in refineries (besides that copro-

duced in steam cracking). So, if consumers pay a price competitive with alternative use in gasoline, supply of benzene will meet all demands for use as a raw material in making

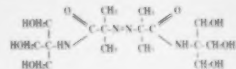
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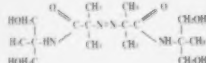
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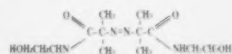
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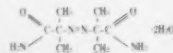
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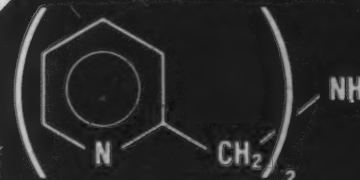
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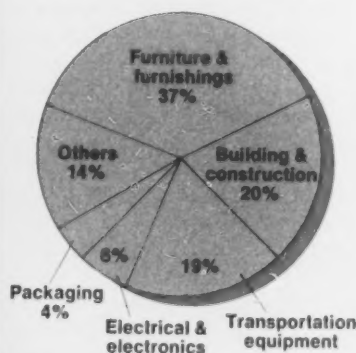
polystyrene, nylon, polyurethanes, and other smaller volume plastics.

Capacity to make intermediates used in some of the smaller volume plastics also has been growing tighter. Capacity to make those intermediates is expanded with much less notice than is given to major ethylene projects. Supplies of intermediates for the specialty plastics are now forecast to adequately meet near-term demands for those plastics.

The many smaller volume (non-commodity) plastics are hard to categorize. One group is called engineering resins. Another may be called performance plastics. Definitions overlap. For example, some resins may be commodities in some uses and engineering resins in others. Nylons, for uses other than in fibers, have long been called engineering resins, but SPI's Committee on Resin Statistics reports production and sales and captive use in a list of thermoplastic resins that includes the major-volume polyolefins. Nevertheless, nylon production exceeds, by several-fold, production of some of the other resins that are reported in the thermoplastics category.

Numerous thermoplastic engineering resins are included in the committee's list: acetals, fluoropolymers, modified polyphenylene oxide, polycarbonate, polyamide-imide, polyimide, polyphenylene sulfide, polysulfone, and thermo-

Three markets dominate polyurethane foam use



1985 production = 2.13 billion lb*

* Latest data available; both flexible and rigid foam.
Source: Committee on Resin Statistics, Society of the Plastics Industry

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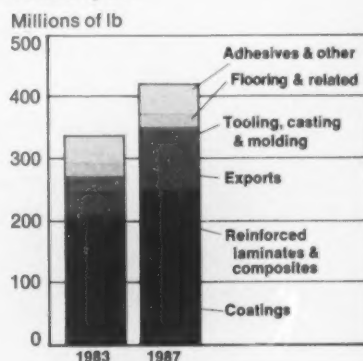
New production record forecast for epoxy resins

Renewed growth in some important uses of epoxy resins will increase production this year to a record of about 420 million lb, up more than 5% from 1986 production. The previous output high was set in 1984 at 406 million lb. In recent years, epoxy resins have become noted for relatively wide swings in production and in certain areas of consumption.

Despite a sizable upturn in production this year, capacity to make epoxy resins will not be strained as is capacity for polyolefins. Current capacity to make the basic epoxy liquid resins is about 500 million lb, or perhaps a little less because of losses in output during shutdowns to change kinds of epoxy products. There is additional capacity to make modified and solid resins from the basic liquids, but that capacity is considered to be downstream processing, not primary capacity.

Because the epoxide group on compounds is so reactive, many different kinds of epoxy resins are offered commercially and more continue to be developed. The kind of curing (cross-linking) epoxy resins undergo offers an even larger variation in final products. Curing agents cover most classes of organic compounds. The number of

Consumption



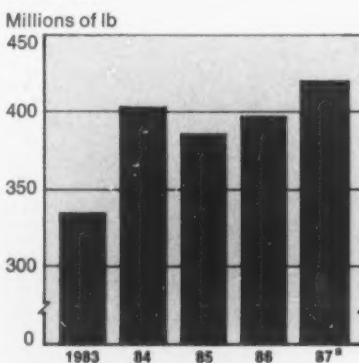
Source: C&EN estimates

chemically different epoxy resins that are of some commercial significance exceeds 100.

Among domestic uses, various types of coatings continue to grow and account for about 40% of total use. A large number of companies make the components of epoxy resins coatings by buying epoxy resins from basic manufacturers. Containers, especially beer and soda pop cans, are the largest market. Automotive primer coatings rank second, a use that varies with the levels of auto production. Other uses of epoxy resins in coatings range from appliances to marine components to some architectural products. Coating uses of epoxy resins are forecast to grow at about the overall rate for all epoxy resins, or 3 to 5% annually.

Laminates and composites use about half the volume of epoxy resins as does the coatings area, with printed circuit boards dominating. Consumption of casting and molding resins that go mostly into electrical and electronic components has slowed. Adhesives and bonding agents generally are made by formulators who sell to consumer and industrial markets. A large number of other small uses make up the remaining consumption.

Production



* C&EN estimate. Source: Committee on Resin Statistics, Society of the Plastics Industry

plastic polyester. Many others are included in other lists, such as polyarylate, polyethersulfone, polyetherimide, and liquid crystal polymers.

Some of these polymers are produced in small quantities, whereas

others now have outputs near 100 million lb. Total production of thermoplastic engineering resins in 1987 could total about 1 billion lb, excluding nylon and thermoplastic polyester.

As with nylon, thermoplastic



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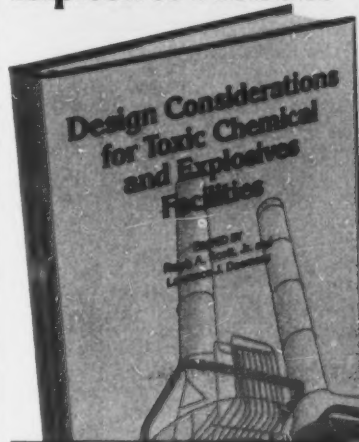
polyester has become so large in volume (1987 production is forecast at more than 1.3 billion lb) that it is reported separately. The rapid rise in production results from its almost total acceptance for 2-L soft-drink bottles. The plastic also is used extensively for making myriad other packaging items, such as bottles for many kinds of noncarbonated beverages, cosmetics, medical products, and food products; as film; and as trays capable of being used either in microwave or conventional ovens.

Many of the engineering and performance resins cost more than the commodity resins. The high cost has limited their ability to capture markets from other materials, particularly from metals, because the cost-performance characteristics were below those of metals. But that situation may be changing, as development work advances the properties of the resins through techniques of alloying and blending polymers, as well as through use of additives, through compounding, and by other methods of fitting plastics to specific needs.

Alloys and blends are not entirely new. One blend, high-impact polystyrenes, was first produced in significant volume many years ago. Plastics that are alloys or blends have definite differences. Polymer alloys are similar to metal alloys in that molecular forces—the dipole moments, hydrogen bonding, and van der Waals forces—are stronger than in blends. They do not, however, have covalent bonds as do copolymers. Because of those intermolecular forces, alloys can resist the effects of heat, light, oxygen, and chemicals better than can blends or single polymers. An example of a commercially available alloy of plastics is polyethylene terephthalate (PET) with polybutyl terephthalate (PBT).

Besides development work in alloys and blends, other work is being done in the area of composites. The combinations of unsaturated polyester and glass fiber are the most common of the composites. Two composites for which demand is expected to grow especially rapidly are the combination of polymers with carbon or with aramid fibers,

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Polyethylene, polystyrene are used to package variety of consumer products

Model Chemical photo

and the coextrusion of two films of plastic.

One area where development work has recently begun is in recycling or reuse of plastics. Previously, such work was mostly concerned with handling waste from fabrication operations. A growing number of companies now are recycling plastic products, predominantly bottles made of PET and high-density polyethylene that are used initially for carbonated beverages, milk, and juices. Development work on recycling is being done on a large scale at the Center for Plastics Recycling Research located at Rutgers University, New Brunswick, N.J. The center is partly financed by the Plastics Recycling Foundation, an organization supported by various manufacturers of resins, processing machinery, and plastic products. It also is supported by packagers who use plastic products and by SPI. Several government agencies, including the National Science

Foundation, provide additional financing.

The need to recycle plastics is a highly visible part of the whole solid waste problem that is regarded with increasing concern by state and local authorities. Chem Systems cites an Environmental Protection Agency study in which plastics are estimated to reach 9.8% by weight of total municipal wastes by the year 2000. State legislatures and Congress are addressing the problem of plastics disposal in oceans and other bodies of water where they damage marine life. Problems of disposal, recycling, or otherwise handling unwanted plastic products, likely will remain a constant and major issue in the industry.

Despite those problems, however, use of plastics almost certainly will continue to grow. Indeed, this innovative material—which has become pervasive during the 20th century—stands to enter the next century with a full head of steam. □

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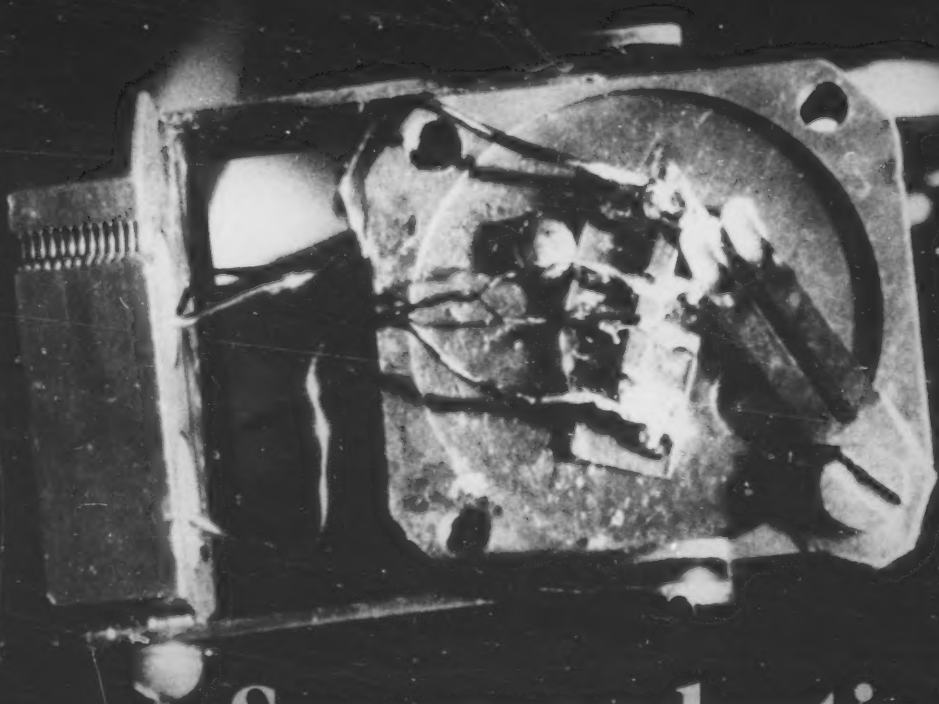
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Superconductivity

The search for a national policy

Page 10

News of the Week

■ Reports of superconductivity above 200 K may be artifacts of the measurement process. **Page 6**

■ OSHA orders a 90% reduction in workplace exposure to benzene to prevent deaths from leukemia and other blood disorders. **Page 7**

■ Lovastatin, a potent drug that can lower cholesterol level in blood 18 to 34%, receives FDA approval. **Page 7**

■ Too few victims of agent orange can be identified to conduct government-mandated study, says Centers for Disease Control. **Page 8**

■ Chemical foreign trade increased strongly in first-half 1987. **Page 8**

■ Public's negative image of chemistry is among topics discussed by international panel at ACS meeting in New Orleans. **Page 8**

■ The 194th ACS National Meeting set several records. **Page 9**

Cover: A scientist at Argonne National Laboratory examines a test cartridge holding a high-temperature superconductor

Letters **4**

Concentrates

Business **15**

Government **19**

Science/Technology **30**

The Departments

New Products **47**

Books **48**

People **51**

Meetings **52**

Newscripts **72**

Business

Revenues for biotechnology companies continued to increase in second-quarter 1987. **Page 17**

Government

National Science Foundation survey provides extensive data on chemists and the current status of chemistry. **Page 23**

Work on new version of budget cutting law will be high on Congress' agenda when it reconvenes this week. **Page 26**

A. L. Laboratories goes to court in attempt to have widely used antibiotic bacitracin removed from EPA's hazardous substances list. **Page 26**

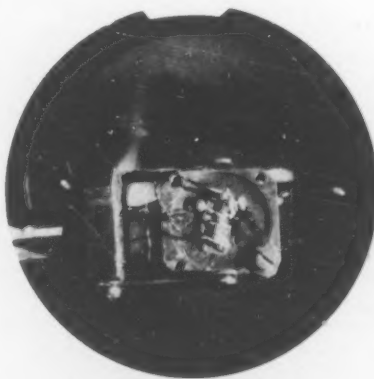
Technology

Commercial laboratory industry thrives on growing demand for analytical testing from private and public sectors. **Page 33**

Redesigned shuttle rocket booster is fired in first full-duration, full-size test. **Page 40**

Gas research program expands with addition of several major oil and gas companies as cosponsors. **Page 42**

Intel Scientific Computers announces line of faster and easier-to-program concurrent supercomputers. **Page 43**



News Focus

Superconductivity drive ignites technology policy debates over need for coordinated government-industry-university programs and for stronger U.S.-Japan research relations. **Page 10**

Revenues Continue To Increase For Biotechnology Firms

Buoyed by growing product sales, licensing fees, and research agreements, financial outlook brightened for most firms in second quarter

William J. Storck, C&EN New York

Increasing product sales and healthier research contracts helped swell revenues at biotechnology firms in the second quarter and, in a few cases, these higher sales increased profitability. The companies registering profits in the second quarter include Biotech Research, Calgene, Centocor, Genentech, Genetics In-

stitute, Genzyme, Molecular Genetics, and Repligen.

Even at companies with little or no sales of products, development is proceeding at such a pace that manufacturing facilities are being built in anticipation of future commercial products.

For 20 U.S. biotechnology firms surveyed by C&EN, revenues for the second quarter increased an average of 42% from the same period in 1986 to a total of \$122 million. Although there was still an aggregate loss for the 20 firms, it narrowed considerably to just \$361,000 from \$11.1 million in the second quarter of 1986. Revenues include product sales, contract research, royalties, and interest revenues.

For the first six months of the year, revenues for the 20 companies totaled almost \$234.0 million, up about 39% from the same period in 1986. However, losses for the companies grew, totaling \$30.9 million in the first six months, compared with \$20.2 million in the year-earlier period.

For the seven companies reporting product sales—Calgene, Cetus, Genentech, Genzyme, Molecular Genetics, Monoclonal Antibodies, and Ribl ImmunoChem, these sales increased almost 90% to \$29.3 million in the second quarter from the same period in 1986. Chief among these was Calgene, whose product sales soared 381% to about \$4.2 million in the second quarter. Product sales now

Second-quarter revenues rose an average of 42% for 20 biotechnology firms

	SECOND-QUARTER 1987						FIRST-HALF 1987					
	Revenues ^a (\$ millions)	Earnings ^b	Change from 1986		Profit margin ^c		Revenues ^a (\$ millions)	Earnings ^b	Change from 1986		Profit margin ^c	
			Revenues	Earnings	1987	1986			Revenues	Earnings	1987	1986
Biogen	\$ 2.659	\$-6.632	-7%	def	def	def	\$ 6.644	\$-12.221	0%	def	def	def
Biotech Research	2.339	0.11	66	def	4.7%	def	4.329	0.183	56	def	4.2%	def
Calgene	6.593	0.84	214	def	12.7	def	13.946	1.333	321	def	9.6	def
California Biotechnology	3.059	-1.742	-21	def	def	1.7%	6.072	-3.326	-15	def	def	def
Centocor	11.873	5.803	49	321%	48.9	17.3	23.819	7.351	64	190%	30.9	17.5%
Cetus	15.426	-1.99	23	def	def	0.1	29.029	-2.936	5	def	def	1.4
Cytogen	2.373	-0.491	317	def	def	def	4.891	-0.771	493	def	def	def
DNA Plant Technology	1.903	-0.172	15	def	def	3.5	3.708	-0.257	25	def	def	1.0
Damon Biotech	1.308	-2.116	2	def	def	def	3.113	-2.201	35	def	def	def
Genentech	47.504	5.695	46	102	12.0	8.7	86.11	8.926	40	95	10.4	7.4
Genetics Institute	4.367	2.573	-10	148	58.9	21.3	9.638	3.861	4	97	40.3	21.2
Genzyme	4.314	0.081	45	def	1.9	def	8.402	0.133	41	def	1.6	def
Immunex	3.638	-0.623	67	def	def	def	7.138	-0.934	105	def	def	def
Integrated Genetics	2.765	-0.896	236	def	def	def	6.171	-0.76	236	def	def	def
Liposome	0.878	-1.856	39	def	def	def	1.75	-3.347	40	def	def	def
Molecular Genetics	1.982	2.413	25	def	121.7	def	4.196	1.507	-3	def	35.9	def
Monoclonal Antibodies	0.75	-4.166	-69	def	def	5.7	2.303	-9.596	-54	def	def	6.4
Repligen	6.024	3.035	519	def	50.4	def	7.562	-17.569	261	def	def	def
Ribl ImmunoChem	0.408	-0.151	-1	def	def	def	0.839	-0.284	4	def	def	def
Synergen	2.066	-0.076	3	def	def	3.2	4.322	0.005	2	-99	0.1	8.8

a Includes sales, contract research, royalty, and interest revenues. b Excludes extraordinary and nonrecurring items where possible. c After-tax income as a percentage of sales.
def = deficit

Biotechnology product sales are still scarce

	Product sales ^a (\$ millions)	% change from 1986	Sales as % of total revenues	
			1987	1986
Biogen	\$ 0	nm	nm	nm
Biotech Research	na	na	na	na
Calgene	4.244	381%	64%	42%
California Biotechnology	0	nm	nm	nm
Centocor	na	na	na	na
Cetus	1.138	105	7	4
Cytogen	0	nm	nm	nm
DNA Plant Technology	0	nm	nm	nm
Damon Biotech	0	nm	nm	nm
Genentech	20.008	111	42	29
Genetics Institute	0	nm	nm	nm
Genzyme	3.133	31	73	80
Immunex	na	na	na	na
Integrated Genetics	0	nm	nm	nm
Liposome	0	nm	nm	nm
Molecular Genetics	0.108	5	5	7
Monoclonal Antibodies	0.550	-71	73	78
Repligen	0	nm	nm	nm
Ribi ImmunoChem	0.101	-21	25	31
Synergen	0	nm	nm	nm

^a For second-quarter 1987, nm = not meaningful, na = not available.

make up about 64% of the firm's revenues, compared with 42% in second-quarter 1986. Genentech also had strong product sales, with a 111% increase to about \$20 million, accounting for about 42% of its total revenues. In the second quarter last year, product sales made up 29% of total Genentech revenues.

Product sales at Cetus more than doubled to \$1.14 million, a 105% gain from 1986. In spite of this increase, product sales still make up just 7% of Cetus' total revenues. In second-quarter 1986, the share was 4%.

Genzyme also recorded significant growth in its product sales, up 31% to \$3.13 million. In spite of this hefty rise, its product sales as a percentage of total revenues dropped to 73% in the second quarter from 80% in the same period last year. Genzyme's president and chief executive officer Henri Termeer says, "We are very pleased with the strong growth of our product sales in the second quarter. Amylase related reagents have grown to be Genzyme's biggest single product, and six new products introduced in the first half as research reagents have kept the growth of that business high."

At Calgene, product sales come primarily, if not totally, from its wholly owned cottonseed subsidiary, Stoneville Pedigreed Seed Co., and this subsidiary was a major factor in Calgene's profitability for the quarter. However, because seeds are a seasonal business and Stoneville operates at a profit only in the second and third fiscal quarters (first and second calendar quarters), Calgene says it will report a loss in its fourth fiscal quarter. Still, it expects a modest profit for the fiscal year.

Genentech's increase in product sales in the second quarter was due primarily to higher sales of Protropin, its human growth hormone.

The biotechnology industry is progressing well enough that a few companies are planning production facilities. At Boulder, Colo.-based Synergen, Larry Soll, president and chief executive officer, says, "Synergen has achieved a major milestone during the second quarter of 1987 with the completion of its \$4 million pilot production plant. We plan to produce recombinant human proteins for clinical trials, including our elastase inhibitor and angiogenesis factor, in the new facility."

Cetus president and chief executive officer Robert A. Fildes comments, "We expect to invest approximately \$42 million in capital assets over the next two years, principally to complete additional pharmaceutical manufacturing facility construction projects, which have begun at our Emeryville, Calif., and Amsterdam, the Netherlands, locations."

Research contracts and interest payments continue to provide benefits at many firms. At Liposome Co., Princeton, N.J., second-quarter revenues include a 19% increase in collaborative research revenues and a 90% increase in interest income.

At Cytogen, based near Princeton, a collaborative agreement with Eastman Kodak provided most of the company's second-quarter contract revenues, and interest income increased \$637,000 over the same quarter a year ago.

Ronald J. Brenner, president and chief executive officer of Cytogen, says, "The joint development program of our targeted radioisotopic cancer imaging technology with Kodak is now in the human clinical testing phase and continues to make encouraging progress. As a result, it has been agreed that the present rate of funding will be maintained for the balance of 1987, and this level of funding by Kodak is expected to continue in 1988."

Other biotech firms also noted clinical testing activities. For example, Liposome reports that it has entered into human clinical trials with an anticancer drug—a liposomal formulation of doxorubicin—in terminally ill patients in an Ontario, Canada, cancer center. Liposome chairman and chief executive officer Edgar T. Mertz says, "It's a very important day in the life of a biotechnology company when it enters human testing. It is further evidence that we are moving closer to our goal of becoming a fully-integrated pharmaceutical company."

Genzyme reports that its first therapeutic product, a treatment for Gaucher's disease, a hereditary metabolic disorder, is doing well in clinical trials and is expected to be introduced in 1989. The company is currently raising a \$10 million R&D limited partnership to fund the development of this program. □

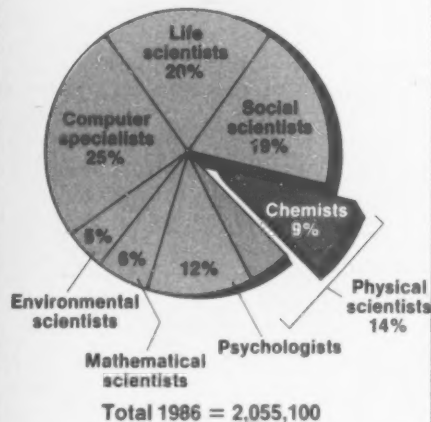
NSF Report Provides Extensive Data About Chemists, Chemistry

Based on three major surveys, study characterizes chemistry as mature field with slower current, future growth than that of other major sciences

David J. Hanson, C&EN Washington

The first publication of a new series from the National Science Foundation provides a wealth of statistical information about chemists and chemistry. Titled "Profiles—Chemistry: Human Resources & Funding," the report includes charts and tables showing trends and the current status of the profession. Though the data are interpreted hardly at all, they show that some trends bode well for chemical scientists and that others are less favorable. In particular, the annual growth in employment for chemists is the lowest of all the major sciences.

Nearly 10% of all working scientists are chemists



Source: National Science Foundation

The data are gleaned from three major surveys conducted every two years by the NSF staff of the Division of Science Resource Studies, each of which gathers data on occupation, highest degree obtained, and profession. These include an experience sample survey of more than 64,000 U.S. scientists and engineers based on information from the 1980 census, a survey on recent science and engineering graduates, and a survey of new recipients of doctoral degrees from U.S. colleges and universities, which samples about 57,000 persons. The first two surveys are used to make up the employment figures. From the three surveys, the number and status of chemists and other scientists and engineers are determined.

The data were organized by economist Melissa J. Lane of the NSF Scientific & Technical Personnel Characteristics Study Group. Lane says this type of review of an individual science has been on the back burner for a long time because data in the separate fields were often difficult to obtain. In the past, NSF has worked with a variety of professional societies, such as the Amer-

ican Chemical Society, in preparing data on some sciences. The chemistry profile is the first of the series, Lane says. The second will be on mechanical engineering and is expected out within the next month.

The data show that chemistry has been a reasonably healthy science over the review period from 1976 through 1986. Chemical research funding by the federal government, for example, has grown at a rate about equal to that for all sciences, not a bad record considering the rapid increase in funding for other areas, such as computer science. With regard to future human resources, women are moving rapidly into chemistry. NSF reports that all the growth in chemistry degrees at the baccalaureate level, about 4% in the past 10 years, has occurred because the number of women becoming chemists has doubled. In 1984, women represented more than one third of the baccalaureate recipients in chemistry. Other minorities, except Blacks, have shared this growth, NSF reports. Black doctoral chemists represent just 1% of the total, unchanged since 1975. The number of Asians receiving doctor-

Industry R&D is the largest employer of chemists

Number of chemists	Industry	Education	Government		Nonprofit organizations	Other ^a	Total
			Federal	State/local			
Basic research	3,000	6,800	1,000	500	600	200	11,900
Applied research	22,700	1,700	3,500	1100	1300	b	30,300
Development	30,700	200	1,000	600	300	b	32,900
R&D management	21,800	1,000	2,100	b	1100	b	25,100
Other management	19,400	2,200	900	1300	700	100	24,700
Teaching	200	24,800	b	b	b	100	25,100
Production/inspection	24,200	200	2,400	4400	400	200	31,900
Reporting, statistical work, computing	3,400	b	500	b	100	100	4,100
Other	6,600	200	b	300	500	600	8,100
TOTAL	132,100	37,000	11,400	8200	5100	1300	195,200

^a Includes consulting, miscellaneous, and not reporting. ^b Too few cases to estimate. Source: National Science Foundation

New chemistry Ph.D.s are at all-time high after falling in 1970s

Number of Ph.D.s	1988	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975
Agricultural/food	—	—	—	—	—	—	11	8	6	14	8
Analytical	285	228	264	190	229	185	207	178	174	152	142
Inorganic	251	233	215	226	188	189	195	201	198	226	229
Nuclear	7	18	13	20	12	14	14	13	24	25	21
Organic	493	525	503	519	494	484	469	454	479	497	605
Pharmaceutical	60	56	78	55	52	52	43	51	50	55	66
Physical	304	329	311	324	275	282	326	310	339	355	393
Polymer	84	63	62	50	62	61	67	57	55	42	40
Theoretical	48	37	46	32	33	47	50	46	38	48	46
Chemistry, general	214	183	177	175	193	157	126	161	146	144	169
Chemistry, other	90	93	88	89	74	67	58	65	62	66	57
TOTAL	1836	1765	1759	1680	1612	1538	1566	1544	1571	1624	1776

Source: National Science Foundation

al degrees has more than doubled during this period as have the numbers of native Americans and Hispanics who have earned Ph.D.s.

The report shows that chemists are more likely than all scientists combined to report some aspect of research and development as their primary work. This includes jobs in management as well as in the laboratory. Almost 39% of chemists are involved primarily in R&D laboratory work, and an additional 13% are in R&D management. The comparable figures for all scientists are 23% and 8%, respectively.

But the work chemists do varies considerably depending on the area of employment. NSF reports that nearly three fifths of chemists employed by industry work primarily in development (23%), production and inspection (18%), or applied research (17%). For chemists in the academic sector, most, as would be expected, are involved in teaching (67%), followed by basic research (31%). This, NSF finds, is actually a dramatic change from a decade ago. Since 1976, the share of chemists primarily involved in teaching has increased 10%, which means that a smaller percentage of chemists are presently doing basic research.

According to the NSF figures, the chemistry profession is suffering from a period of slow growth. The annual growth rate in employment of chemists of only 4% is half the rate for all sciences combined. Only the employment of medical scientists and oceanographers had lower growth rates. NSF's Lane says this is the result of the current bal-

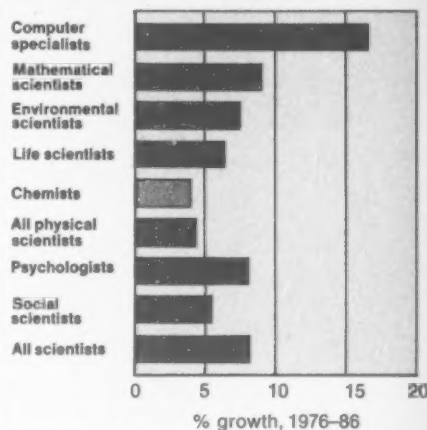
anced labor market in chemistry. Not many chemists are unemployed, she says, but at the same time the number of chemistry graduates isn't growing either. There has been a major shakeup in chemical employment, Lane says, stemming from a restructuring of the industry begun several years ago.

NSF finds that chemists' salaries are higher than those of the average scientist, but lower than those of other physical scientists, such as physicists. The average salary for chemists in 1984 is reported at \$37,100 and at \$34,500 for all scientists. The average salary for physicists is \$44,200. Economist Lane says it is surprising that chemists' salaries are not higher, particularly because they are more likely to have a doctorate than are professionals in most other sciences.

Perhaps the slower job growth rate and declining enrollments are the basis for another finding. The average age of chemists is rising faster than that for all sciences. NSF reports that in 1986 almost 40% of chemists employed in the U.S. were more than 50 years old, compared with less than one third for all scientists. In 1976, three fifths of employed chemists were under 40 years old. In 1986, however, only 35% were under 40. For all scientists, 45% are less than 40 years old. On the other end of the scale, in 1986 only 11% of employed chemists were under 29 years old, whereas 16% of all scientists were less than 29. This means, of course, that as older chemists leave, there may be fewer experienced chemists to replace them.

Based on its data, the Bureau of

Employment growth for chemists has been low for past decade



Source: National Science Foundation

Labor Statistics projects that employment in chemistry will continue to grow slowly over the next decade, probably 5 to 14% through 1995. This is expected to be less than the average growth rate for all sciences, as it has been for the preceding decade. The NSF report appears to concur, showing chemistry to be a mature field held steady by its large size and broad scope. Although the future of chemistry as a career is characterized as a declining one, chemists obviously can get steady work in a large variety of other related fields.

Single copies of the NSF report may be obtained from the National Science Foundation, 1800 G St., N.W., Washington, D.C. 20550. The full citation for the document is Profiles—Chemistry: Human Resources & Funding (NSF 87-307). □

Contract Labs Respond to Growing Demand for Analytical Testing

Commercial lab industry thrives on increasing call by companies, state and federal governments for drug, environmental monitoring

Ward Worthy, C&EN Chicago

Analytical chemistry, once merely a science, is now a fast-growing industry as well, thanks to Superfund and other legislation. Indeed, some modern analytical laboratories are really factories: Production lines process thousands of samples and computerized data systems turn out reams of paperwork.

According to various estimates, for-hire commercial labs had revenues of \$250 million to \$300 million in 1986 for environmental analyses alone. In-house environmental testing accounted for a similar amount. Drug testing brought another \$200 million to \$300 million. And, according to various predictions, the analytical services market will grow at a compounded annual rate of 25 to 40% over the next five years.

Fair to say, all this wouldn't be happening without the impetus provided by the U.S. and state governments. On the environmental side, for example, at least eight federal laws mandate laboratory analyses of one kind or another. Most of the recent growth in the lab industry has been generated by the Comprehensive Environmental Response, Compensation & Liability Act, better known as Superfund. However, compliance with the other laws—the Resource Conservation & Recovery Act, the Toxic Substances Control Act, the Clean Water Act, the Clean Air Act, the Safe Drinking Water

Act, the Marine Act, and the Federal Insecticide, Fungicide & Rodenticide Act—also entails a lot of chemical analysis.

According to Stanley P. Kovell, special assistant to the director of the Environmental Protection Agency's Office of Emergency Remedial Response, it was obvious even before Superfund was passed that the agency's in-house laboratories could not deal with the expected influx of samples. So Kovell, in 1979, began to set up what came to be known as the Contract Laboratory Program (CLP), whereby private laboratories would furnish "state-of-the-art chemical analysis on a high-volume basis." Currently, Kovell says, Superfund accounts for about 95% of CLP's business. He notes, however, that CLP is designed to be "program neutral," and that work for non-Superfund clients is increasing.

The number of samples analyzed by private laboratories under CLP rose dramatically, from 1527 in fiscal year 1980 to 70,891 in fiscal 1985. In fiscal 1986, when Congress was wrestling with Superfund renewal and funds were in doubt, the number dropped slightly. This year, however, the operation is back in full swing. EPA estimates that just under 100,000 samples will be analyzed by CLP laboratories in fiscal 1987.

Moreover, CLP is only the tip of the iceberg. For example, Robert E. Finnigan, senior vice president of Finnigan MAT, a maker of gas chromatography-mass spectrometry (GC-MS) instrumentation and a major beneficiary of lab industry growth, estimates that U.S. environmental laws required the analysis of 150,000 to 180,000 samples in 1986. In addition, state and local governments accounted for 150,000 to 200,000 environmental samples



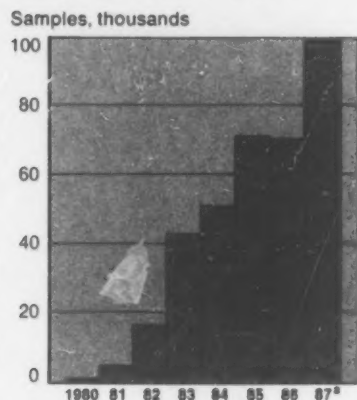
Kovell: huge influx of samples

and private industry for another 250,000 to 300,000.

The CLP approach has wrought changes in the way analytical chemistry is done. It's no longer enough that an analysis be scientifically credible. According to EPA's Kovell, the underlying assumption is that the lab data will be used in litigation, with the government bearing the burden of proof. To provide "legally defensible" analytical results, the agency had to develop a program with a high level of quality assurance, extensive documentation, maintenance of chain-of-custody information on samples, and a high degree of intra- and interlaboratory consistency. Laboratories have to pass proficiency tests before they can bid on contracts.

When the program began, no validated EPA-approved methods were available. Therefore, developing and specifying analytical methods was one of the first orders of business.

Contract Lab Program analyses up sharply



Note: Fiscal years. ^a Estimated.
Source: Environmental Protection Agency

Methods have been refined through the years. Currently, CLP offers a menu of routine and special analytical services for inorganic analyses, organic analyses, and dioxin analyses.

Inductively coupled plasma (ICP) spectrometry is the method specified for most inorganic analyses. However, atomic absorption (AA) spectrometry is prescribed for elements such as mercury and selenium that aren't amenable to ICP. Colorimetric methods also are used. For organic analyses, GC-MS is prescribed. Dioxins, like other organics, are analyzed by GC-MS. However, some dioxins are highly toxic. They require special safety precautions, which not every lab can provide. Consequently, dioxins are handled under separate contracts.

The above description greatly oversimplifies things, of course. In fact, EPA publishes a thick user's guide to CLP that spells out in great detail what shall be done and how. Provisions are made for various types of sample matrix and for varying concentrations. Quality-control procedures are specified, as are documentation requirements.

It shouldn't be inferred that techniques other than ICP, AA, and GC-MS are somehow inferior, or that they have no place in environmental analysis. That's not the case. As just one example, although ICP and AA are the evidentiary methods for inorganic analyses, ion chromatog-

raphy (IC) is also very useful in the field, particularly in wastewater and groundwater analysis. IC also can be used as a scanning tool for metals analysis with minimal sample preparation, with later confirmation by ICP or AA. Similarly, in drug testing, it's cost effective to use radioimmunoassay or enzyme immunoassay tests for preliminary screening; GC-MS is used only to confirm the suspected "positives."

Just the same, there's little doubt that CLP approval of a methodology is a boon to companies making the instruments that the methodology requires. For example, companies like Hewlett-Packard and Finnigan MAT, major producers of GC-MS systems, have benefited greatly from the fact that GC-MS is the approved CLP method for organic analyses.

Robert Finnigan, who pioneered the first commercial GC-MS systems, admits that his company lobbied hard to get EPA approval. And he enjoys the fact that Finnigan MAT has perhaps 65% of the market for GC-MS systems. He adds, however, that GC-MS is now more cost-effective than ever. For example, although the environmental market for analytical services will grow an estimated 35 to 40% per year over the next five years, the market for GC-MS—and for liquid chromatography-mass spectrometry (LC-MS) and mass spectrometry-mass spectrometry systems—will grow only about 20% yearly during the same period. There are two reasons for the difference in rates, Finnigan says. First, the laboratories increasingly will go to multiple-shift operation. Second, they will enjoy higher productivity with the newer analytical instrument systems.

As might be expected, there's a constant conflict between the need for standardization of procedures and the desire to use the latest and best procedures. Mark Carter, a senior manager at Enseco, one of the largest commercial labs, describes the situation.

"I spent seven years at EPA," Carter says, "so I know the dilemma it faces. The requirements to get new procedures adopted are agonizing. I believe it stifles the advancement of the science. But I don't mean to be critical of the agency. EPA has to balance between pushing the science along and yet making sure that the information it generates will stand up in court—because it is, after all, a regulatory agency."

Joan Fisk, manager of CLP's national organics program, agrees that nothing is going to displace GC-MS in the near future. "We're investigating LC-MS methods," she says, "but we're not ready to implement them." However, Fisk adds, methods are constantly being refined. Currently, a lot of attention goes to sample preparation and cleanup procedures.

Kovell admits that CLP's main mission necessitates that methods be standardized. However, he points out, methods development is another CLP mission, and CLP lets contracts for that purpose as well as for environmental analyses. Also, the laboratories operating under CLP provide an excellent means for validating new procedures under "real world" conditions. Quarterly "technical caucuses" bring together participants from all parts of the CLP organization for evaluation of analytical methodologies.

All true, says Enseco's Carter, but it's still a slow process. For instance,

Big laboratories expected to get bigger

	Professional staff ^a	Lab revenues, \$ millions		
		1986	1987 ^b	1988 ^c
Enseco	425	\$29.5	\$36.5	\$51.0
Environmental Treatment & Technologies ^c	400	20.3	28.0	35.0
CompuChem	400	15.2	25.9	32.4
International Technology ^d	400	20.7	23.7	29.0
Thermo Analytical	340	16.6	20.6	25.7

^a Approximate. ^b Estimated. ^c Laboratory revenues calculated as 20% of company's total revenues. ^d Laboratory revenues calculated as 10% of company's total revenues. Source: First Analysis Corp.

Enseco and Perkin-Elmer are working together to promote inductively coupled plasma-mass spectrometry (ICP-MS) methods. Perkin-Elmer is furnishing the equipment and Enseco is developing applications and doing the "regulatory liaison" needed to get ICP-MS technology approved by EPA. Carter is optimistic about the eventual outcome, but he notes that it's been a long haul.

"There's so little effective communication between the research centers and the program offices," Carter asserts. "We feel the most effective way to get these new techniques approved is to collect the information that's required and communicate directly with the program offices. It isn't just a matter of showing you're doing good science. You've got to go through that agonizing regulatory setting. It's difficult, but it's essential."

The drive for increased productivity is also affecting the structure of the lab business. Steven F. Bouck, who tracks the analytical laboratory industry for First Analysis Corp., a Chicago research investment firm, notes that it's a highly fragmented industry with more than 500 players. Bouck estimates, however, that five of those companies will have combined lab revenues of more than \$130 million in 1987. The five firms are Enseco, Environmental Treatment & Technologies Corp. (ETTC), CompuChem, International Technology Corp. (IT), and Thermo Analytical Inc.

Although small labs will continue to have their own niches, consolidation is occurring rapidly through mergers and acquisitions, Bouck explains. For example, Enseco was formed by the merger of Rocky Mountain Analytical Laboratory (Denver), California Analytical Laboratory (Sacramento), and several smaller firms. Rocky Mountain Analytical's special strength is inorganic analysis; California Analytical's is GC-MS. Similarly, Thermo Analytical, the laboratory arm of Thermo Electron, has acquired several smaller laboratories.

Several factors promote the use of the larger companies, Bouck says. For one thing, test requirements, as they become more sophisticated, require more expensive equipment. Also, the newer EPA contracts require greater sample throughput and more equipment redundancy. The larger labs offer a wider variety of services and equipment. And the larger labs are often perceived, rightly or wrongly, as having better quality-control programs. On the other hand, the smaller labs often have the virtues of being closer to their customers and responding more quickly to their needs.

Buyers of analytical services also may choose between companies that do nothing but lab work—like Enseco and CompuChem—and companies that are "vertically integrated" (that is, they also provide services in other areas of hazardous waste remediation, including engineering, consulting, transportation,



Data management is an important aspect of modern laboratory operation

and disposal). Among the larger companies, ETTC and IT are examples of the latter approach. Thermo Analytical is moving in that direction too. After merging with Thermo Water Management (another Thermo Electron subsidiary), it will be renamed Thermo Environmental.

Both approaches have their pros and cons. The vertically integrated companies offer the convenience of "one-stop shopping" for hazardous waste problems, Bouck points out. However, their labs tend to be more specialized, with capabilities tailored to support the company's other operations. The lab-only companies usually offer a broader menu of lab services. And they're presumed to be more objective, because they have no other axes to grind.

Other factors play a role as well. For example, CompuChem, the leader in GC-MS analyses, favors the economies of scale that it can achieve with its one "megablab" at Research Triangle, N.C. However, CompuChem recently started a second lab in California, for the simple reason that a company has to have a lab in California to be "certified" there. In fact, the five largest lab companies all now have facilities in California.

Labs both big and small may bid for EPA contracts under CLP, once they have passed proficiency tests. And a lot of them have been bidding. According to EPA, a total of 91 labs had contracts under the program as of July 31. However, contracts are continually ending, new contracts are being let, and the num-



International Technology Corp. uses negative-pressure room for dioxin analysis

ber of participating labs has been increasing substantially.

At the same time, because contracts are awarded on a low-bid basis, the competition has driven prices down to what one lab spokesperson calls "ridiculously low levels." In fact, many of the smaller labs probably make little if any money on their CLP work. They seek it out just the same because acceptance into CLP provides a measure of credibility that they can use as a selling point in their dealings with private clients—who will end up paying considerably more per sample than EPA.

On the other hand, the labs don't want to be too dependent on government work. The Superfund slowdown in 1986 was hard on labs that didn't have other work to fall back on.

Among the problems facing the analytical lab industry, several lab executives mention a lack of qualified personnel. There is no shortage of analytical chemists, they say, but there is a shortage of people with the specific qualifications needed for environmental work, particularly in the GC-MS field and at senior levels. The major labs have recruiting programs and in-house training programs that have tended to ease the shortage somewhat. However, the demand has driven up salaries and has led to job-hopping.

Despite the essential role that computers play in the modern analytical laboratory, information management also continues to be a problem, especially for the largest labs. For example, Enesco's Carter says, "There isn't one laboratory information management system (LIMS) available that can support a company of our size, or support the sophistication of the work that we're doing." The difficulty, he says, is that existing systems, not having been designed specifically for environmental work, often aren't flexible enough to give the customers what they need. Therefore, Enesco is developing its own system. However, Carter adds, existing LIMS can be quite satisfactory for many laboratories. For that matter, a good "paper system" is often sufficient for smaller labs. □

Redesigned shuttle rocket test-fired

Nineteen months after the fatal explosion of the space shuttle Challenger that grounded most of its space program the U.S. last week reached a major technological and psychological milestone toward getting back into space: the first full-duration, full-size test firing of the shuttle's solid rocket booster, redesigned to eliminate the problems that caused the Challenger disaster.

In an atmosphere recalling launches into space from Cape Canaveral, dignitaries, the media, and thousands of members of the public gathered at a remote, barren mountain valley near Brigham City, Utah. For two minutes, the valley shook with the roar of a horizontal test firing of 1.1 million lb of solid propellant, and plumes of smoke shot thousands of feet into the air.

When this first "development motor" firing was over, officials of the National Aeronautics & Space Administration and of Morton Thiokol, prime contractor for the booster, pronounced the test successful, based on initial indications. However, they cautioned, it will take several weeks for engineers to take apart the rocket, inspect its parts, and make a full analysis of the results.

Their smiles were dampened somewhat by embarrassment over repeated delays of the test, postponing it by three days. The cause was not in the booster rocket, but

in its ground support systems—a failed coupling in a water hose used to cool the booster, and difficulty after an aborted test in resetting the computers for the countdown.

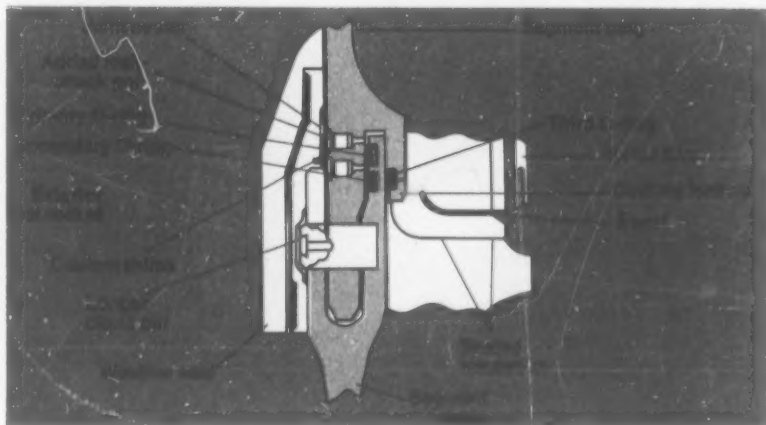
Some 520 instruments monitored performance of the 126-foot-long, 12-foot-diameter booster. Thiokol and NASA have redesigned a number of features, including the exhaust nozzle at the rocket's rear and the case-to-nozzle joint. However, particular interest focuses on the three field joints—tang-and-clevis (tongue and groove) joints connecting the four rocket casting segments—which are usually assembled in Florida before launch. This is because failure of an aft field joint, allowing hot gases to pass through, caused the Challenger explosion.

When Thiokol engineers open up the rocket, the primary thing they'll be seeking is evidence of any hot gas getting through the field or case-to-nozzle joints.

Features added to the field joints to prevent such seal failure (C&EN, July 6, page 4) include a tang capture latch (an extra metal lip) and custom-fit shims that limit movement between tang and clevis. The new design also uses sealed insulation bonded with a pressure-sensitive adhesive (eliminating the problem-causing putty used in the Challenger boosters), and adds a J-shaped deflection relief flap to reduce stresses and increase sealing action under motor pressure.

Further changes include a third O-ring seal, longer clevis pins, and

Redesigned rocket joint adds heater, capture feature



Scientific news from the
ACS meeting in New Orleans

SEPTEMBER 14, 1987

CHEMICAL & ENGINEERING

NEWS

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Fungus explored as
new weapon against
cancer

P. 17

News of the Week

■ **International experts meeting in Geneva make progress toward reaching agreement on reducing nitrogen oxides emissions into the atmosphere.** Page 4

■ **Presidential AIDS commission met for first time last week, amid much controversy about Administration's efforts to combat the disease.** Page 5

■ **GAF chairman Samuel Heyman proposes management-led buyout of the specialty chemicals and building products company in deal that is worth about \$2.3 billion.** Page 5

■ **Increased cancer risk in Marines is linked to Vietnam war service in study conducted by Veterans Administration.** Page 6

■ **Chemistry is key factor for U.S. to meet challenge of foreign competitors in technology for information systems, says new report.** Page 6

Business

U.S. chemical productivity slowdown in the second quarter could signal coming recession in chemical economy. Page 9

Government

Legislation to update U.S. pesticide laws must resolve questions of reregistration fees, groundwater contamination, among others. Page 12

From the ACS meeting: analysis of the costs and benefits of federal health and safety rules; U.S. attempts to define stance on reduction of chlorofluorocarbons for global treaty negotiations. Page 13

Technology

Also from the New Orleans meeting: advances in direct catalytic conversion of methane to fuel; review of petroleum firms' cooperative environmental effort; development of new process for production of piperidine; and improvements in fluid catalytic cracking. Page 19

Science

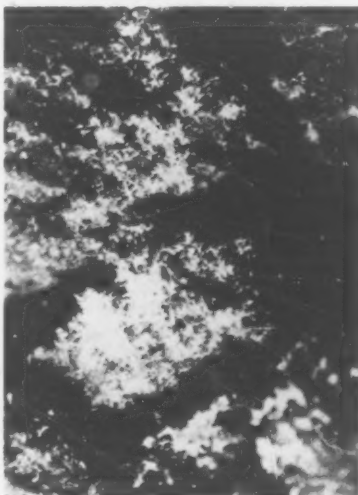
From the national meeting: Simple route to chiral glycerol derivatives from low-cost starting material has been developed. Page 23

ACS News

Photographic album of society's national meeting in New Orleans shows wide variety of activities. Page 28

Cover: Scientists at USDA Forest Products Laboratory test ability of white rot fungus to degrade pentachlorophenol in soil

Letters	2
Editor's Page	3
Concentrates	
Business	7
Government	11
Science/Technology	16
The Departments	
Meeting Briefs	24
Meetings	30
Newsclips	52



Cover Story

ACS meeting symposium on emerging detoxification technologies unveils promising use of white rot fungus in treatment of organic hazardous waste. Page 17

Chemical Productivity Growth Slows in Second Quarter

William J. Storck, C&EN New York

Growth of the U.S. chemical industry's productivity slowed down in the second quarter from the three previous quarters. However, it's too early to panic. It's nevertheless worrisome, as the second quarter normally exhibits stronger productivity growth than does the first quarter, with a seasonal slowdown coming in the third quarter of the year.

Also troublesome is that productivity (output per hour) for chemi-

cals and allied products grew more slowly in the second quarter than did productivity for all manufacturing industries (including the chemical industry) on a quarter-to-quarter basis and almost equaled growth in the manufacturing sector on an annual basis. Unit labor costs (production wages per unit of output) for chemicals actually rose in the second quarter from the first as they continued to fall for all manufacturing. On an annual basis, the chemical industry's unit labor costs fell more slowly than they did for

all manufacturing. In the first quarter, the annual decline for both groups was the same. The chief cause for concern is that chemicals' poor performance in relation to all manufacturing in productivity growth and in unit labor cost declines in the past has been a leading indicator for a slowdown or recession in the chemical economy.

One mitigating factor is the continuing long, slow growth of both the chemical industry and the economy in general in the current ex-

Second-quarter chemical productivity plateaued after first-quarter jump . . .

Indexes, 1977 = 100	Quarters, 1987		Quarters, 1986				Quarters, 1985				Quarter, 1984	
	2nd	1st	4th	3rd	2nd	1st	4th	3rd	2nd	1st	4th	
CHEMICALS AND ALLIED PRODUCTS												
Production	138.2	137.8	133.6	134.1	132.8	131.8	127.9	128.1	126.9	125.8	127.9	
Workhours	93.5	93.2	94.2	93.4	93.1	93.4	93.8	93.9	94.5	95.1	94.9	
Productivity	147.9	147.8	141.9	143.6	142.7	140.6	136.3	136.4	134.1	132.3	130.2	
Hourly production wages	191.0	189.8	188.8	186.9	184.8	184.1	183.9	180.7	178.6	177.3	176.5	
Unit labor costs	129.1	128.4	133.1	130.2	129.5	130.9	134.9	132.5	133.1	134.1	135.5	
ALL MANUFACTURING												
Production	133.0	131.8	130.4	129.4	128.4	128.4	127.4	126.8	126.3	125.3	124.9	
Workhours	92.8	92.8	93.1	92.6	92.8	93.6	93.5	92.9	93.0	93.8	94.6	
Productivity	143.3	142.0	140.1	139.7	138.3	137.3	136.3	136.5	135.6	133.7	132.0	
Hourly production wages	173.8	173.2	172.1	171.0	170.8	170.5	169.4	167.8	167.0	163.6	163.8	
Unit labor costs	121.3	121.9	122.9	122.4	123.5	124.2	124.3	122.9	123.2	122.4	124.1	

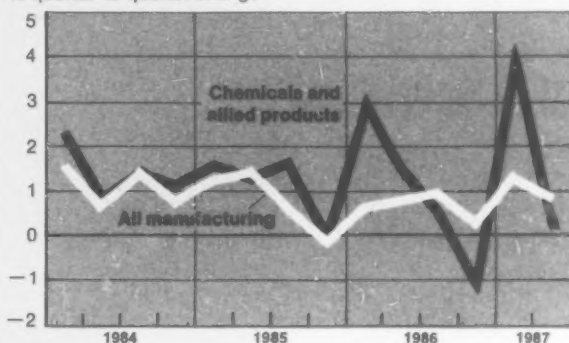
. . . but first-half 1987 is up markedly from 1986 average

Indexes, 1977 = 100	1987*	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977
CHEMICALS AND ALLIED PRODUCTS											
Production	138.0	132.9	127.1	121.6	113.9	103.8	112.6	106.4	113.3	106.3	100.0
Workhours	93.4	93.5	94.3	95.0	93.9	95.2	101.7	101.0	103.1	102.2	100.0
Productivity	147.9	142.1	134.8	128.0	121.3	109.0	110.7	105.4	109.9	104.0	100.0
Hourly production wages	190.4	186.1	180.1	172.7	164.8	155.0	141.8	129.2	118.2	109.2	100.0
Unit labor costs	128.8	130.9	133.7	135.0	135.9	142.2	128.2	122.6	107.6	105.0	100.0
ALL MANUFACTURING											
Production	132.4	129.2	126.4	123.4	113.9	102.2	110.5	108.2	110.7	106.1	100.0
Workhours	92.8	93.0	93.3	94.8	88.2	87.0	97.9	98.9	106.2	104.5	100.0
Productivity	142.7	138.9	135.5	130.1	124.8	117.5	112.9	109.4	104.2	101.5	100.0
Hourly production wages	173.5	171.1	166.9	161.5	155.4	149.6	140.7	128.1	118.0	108.6	100.0
Unit labor costs	121.6	123.3	123.2	124.1	124.4	127.3	124.7	121.5	113.2	107.0	100.0

* First half Sources: Federal Reserve Board, Department of Labor

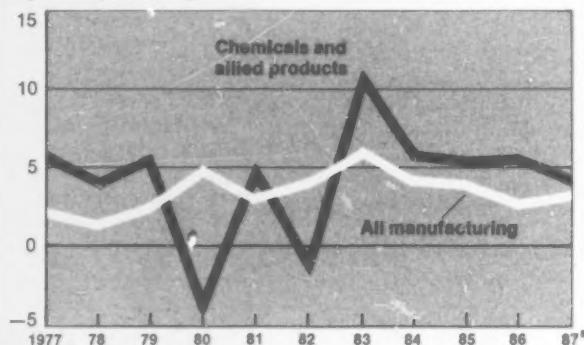
Second-quarter productivity gain for chemicals lagged all manufacturing ...

% quarter-to-quarter change



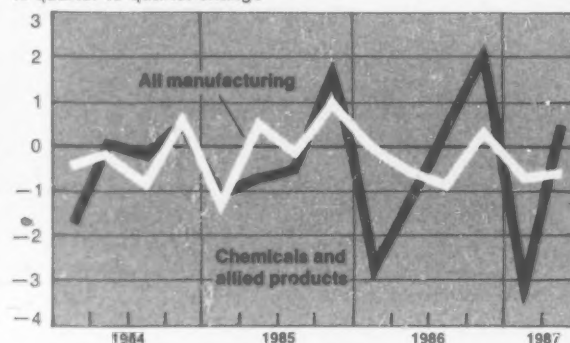
Productivity rose faster for chemicals in the first half ...

% year-to-year change



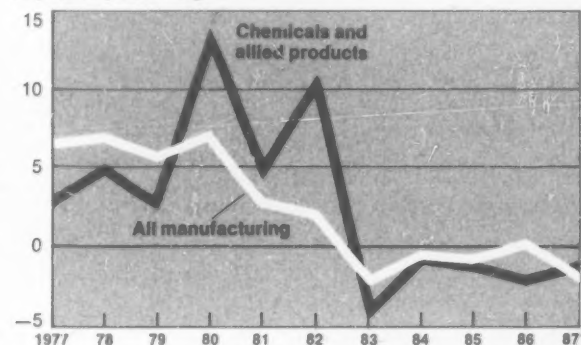
... and unit labor costs rose for chemicals but fell for manufacturing

% quarter-to-quarter change



... but unit labor costs dropped less than for all manufacturing

% year-to-year change



Note: Productivity is output per workhour, calculated by dividing indexes for production by indexes for workhours of production employees. Unit labor costs are labor costs per unit of output, calculated by dividing indexes for wages by indexes for output per hour. **a** For first-half 1987, percentage change is from first-half 1986.

Sources: Department of Labor, Federal Reserve Board

pansion. This has led to an erratic pattern in chemical productivity for a number of quarters. In general, year-to-year improvement in productivity and unit labor costs has been pretty steady and gains have been substantial. However, quarter-to-quarter changes have shown swings in the amount of improvement in the past few years and have in the case of productivity even declined in a couple of quarters.

Using government data for production and workhours, C&EN estimates that chemical productivity in the second quarter of 1987 increased only 0.1% from the first quarter to an index of 147.9 (1977 = 100), but this figure was up 3.7% from the second quarter of 1986. For all manufacturing, productivity rose 0.9% on a quarter-to-quarter basis to an index of 143.3, and on an

annual basis, it was up 3.6% from the comparable period in 1986.

For the first half of this year, productivity for chemicals and allied products grew 4.4% to an index of 147.9, whereas that for all manufacturing grew 3.5% to an index of 142.7.

In the second quarter, unit labor costs, which in good times are expected to decline, did indeed fall on an annual basis both for chemicals and for the broader manufacturing sector. But on a quarter-to-quarter basis, unit labor costs rose for chemicals for the third time in the past four quarters. This measure for chemicals and allied products was up 0.5% to an index of 129.1 in the second quarter of this year from the first quarter. On an annual basis, this measure declined a scant 0.3% from the same quarter

a year ago—the smallest annual rate of decline since this measure began to fall at the beginning of 1983.

For all manufacturing, unit labor costs in the second quarter dropped 0.6% from the first quarter of 1987 to an index of 121.3. They are down 1.8% from the same period a year earlier.

For the first half of this year, unit labor costs for chemicals and allied products were down 1.1% to an index of 128.8 from the same period last year. However, the index for all manufacturing declined a more rapid 1.8% to an index of 121.6.

Chemical unit labor costs declined 1.6% in the first half of 1987 from the average for all of 1986, whereas productivity was up 4.1%. Unit labor costs for all manufacturing fell 1.4% from last year's average and productivity rose 2.7%. □

on this issue was fueled this spring by a report from the National Academy of Sciences that said there could be some risk to human health from residues, at the tolerance levels set by EPA, on both processed and unprocessed foods.

Groundwater contamination by pesticides is another serious concern, and the Senate bill takes a strong stance on the issue—too strong, according to NACA. It says the bill would essentially "establish a mandatory, universal non-degradation policy for nearly all groundwater. It does so by defining virtually all underground water as drinking water." The fear of polluting groundwater, even if it never would be used for drinking, NACA says, will deter farmers from

using many agricultural chemicals. The House version is not that severe.

Another important section involves patent extension. Patent term extension, to allow a holder to recoup some of the patent life eaten up by regulatory review, is in the Senate bill, but not the House version. Generic pesticide manufacturers have floated the idea of allowing them to test generic products before a patent expires, a concept that has always been rejected before and could shorten the effective life of a patent by several years. Environmental groups are also making a strong plea for a provision permitting individuals to sue companies under FIFRA, an idea that is stiffly opposed by the pesticide industry.

David Hanson, Washington

Cost-benefit analysis of federal regulations

NEW ORLEANS

If federal agencies used more realistic risk and benefit estimates in determining what and how much to regulate, society as a whole would be much safer. And more benefits can be obtained, at less cost, from regulations that seek to ensure safety than from those that attempt to protect health.

Those are the admittedly "provocative" and "controversial" views of John F. Morrall III, an economist with the Office of Management & Budget. He presented results of his analyses of the costs and benefits of 44 federal health and safety rules at a symposium on risk assessment and the establishment of tolerances and standards for potentially toxic chemicals sponsored by the Division of Chemistry & the Law.

Morrall has reviewed health, safety, and environmental regulations for the executive office of the President during the past three Administrations. It is OMB's job, he explains, to obtain data from the scientific community and, working within the relevant legal parameters, to make recommendations on the

cost-effectiveness of toxic chemical and safety regulations.

His analyses of the 44 regulations show that they vary enormously in cost effectiveness, from a cost of \$100,000 per life saved for the National Highway Traffic Safety Administration's steering column standard to \$72 billion per life saved for the Occupational Safety & Health Administration's worker exposure standard for formaldehyde.

For OSHA, the one agency that issues both safety and toxic chemical regulations, the median value of cost-per-life-saved estimates for seven safety rules in the analysis is 123 times higher than for six cancer regulations, Morrall notes, adding that even OSHA's most costly safety regulation—for grain dust—costs less per life saved than the least costly cancer regulation—for asbestos.

"On the basis of these data it can be concluded," Morrall says, "that with \$1 billion in resources available for risk reduction, we could save 2000 lives through safety regulations or 27 lives through cancer regulations."

These differences between health and safety regulations should not be surprising, Morrall says. In large part, they are dictated by statute. The safety statutes, such as those authorizing NHTSA, the Consumer Product Safety Commission, or even OSHA's safety regulations, almost invariably speak in terms of reasonable, practicable, appropriate, and so forth, he notes. In contrast, the health statutes speak in terms of absolute or near absolute protection.

"Although these differences in cost-effectiveness may appear ex-

OSHA safety rules more cost-effective than health rules

Regulation	Status and year	Initial annual risk estimate ^a	Lives saved annually	Cost per life saved (\$ thousands, 1984)
SAFETY				
Oil and gas well service	Proposed 1983	1.1 in 10 ³	50,000	\$ 100
Underground construction	Proposed 1983	1.6 in 10 ³	8,100	300
Servicing wheel rims	Final 1984	1.4 in 10 ⁵	2,300	500
Crane-suspended personnel platform	Proposed 1984	1.8 in 10 ³	5,000	900
Concrete and masonry construction	Proposed 1985	1.4 in 10 ⁵	6,500	1,400
Hazard communication	Final 1983	4.0 in 10 ⁵	200,000	1,800
Grain dust	Proposed 1984	2.1 in 10 ⁴	4,000	2,800
HEALTH				
Asbestos	Final 1972	3.3 in 10 ⁴	396,000	7,400
Benzene	Final 1987	8.8 in 10 ⁴	3,800	17,100
Ethylene oxide	Final 1984	4.4 in 10 ⁵	2,800	25,600
Acrylonitrile	Final 1978	9.4 in 10 ⁴	6,900	37,600
Coke ovens	Final 1976	1.6 in 10 ⁴	31,000	61,800
Asbestos	Final 1986	6.7 in 10 ⁵	74,700	89,300
Arsenic	Final 1978	1.8 in 10 ³	11,700	92,500
Ethylene dibromide	Proposed 1983	2.5 in 10 ⁴	0.002	15,600,000
Formaldehyde	Proposed 1985	6.8 in 10 ⁷	0.010	72,000,000...

^a Annual deaths per exposed population. Source: John F. Morrall III

traordinary," Morrall says, "they are probably understated by a large margin." For example, cancer risks tend to be overestimated. Safety risks, on the other hand, are less likely to be overestimated because of the greater availability of safety data.

It's pretty well known that agencies, in dealing with health issues, provide upper-bound risk estimates that are very conservative. "It's easy to understand, on a case-by-case basis," says Morrall, "why an individual scientist or even an agency finds it personally or politically easier to provide upper-bound rather than best-risk estimates. But in the aggregate, this approach does more harm than good in the cause of making our society safer."

This is not to say that Morrall denies the need to regulate toxic chemicals. In fact, he believes that "we tend to overregulate specific chemicals or activities, but under-regulate in terms of the total number of chemicals or activities. I think

this is due to our political-legal process, which causes agencies not to begin regulating unless there is a probability of harm, but once harm is established to regulate too stringently."

The system, he contends, "has problems with the idea that a chemical we are only 50% sure is a carcinogen of potency x should be regulated at 50% the stringency of a sure carcinogen of potency x . Now we either don't regulate or regulate as though the probability were 100%."

According to Morrall, "This problem could be overcome if we truly used effective-value or most-likely risk assessment methodology. We are slowly moving in that direction," he says, "as the science of risk assessment and our understanding of the etiology of cancer advance. The recent incorporation of pharmacokinetic data into risk assessment methodology is a sign of that progress."

Janice Long, Washington

U.S. defining stance on global CFC treaty

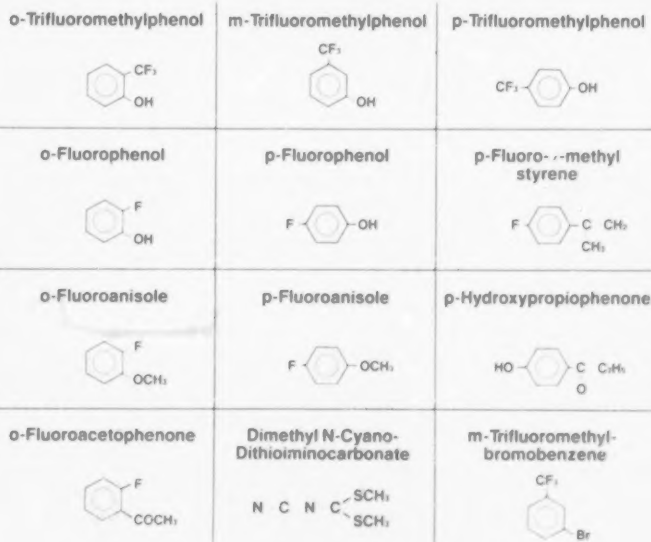
NEW ORLEANS

A final negotiating session on a draft treaty to freeze and then cut production of chlorofluorocarbons (CFCs) begins in Montreal this week. The draft treaty has been agreed to in principle by 31 nations, including the U.S., which has been represented by the Department of State and the Environmental Protection Agency.

The U.S. position has been that an immediate freeze on current production levels of certain CFCs, followed by an eventual 95% cut in the production of all CFCs is needed to protect the stratospheric ozone layer. As it is now written, the draft treaty calls for an immediate freeze of production levels and imports of several fully halogenated CFCs, followed by a 50% reduction in production of CFCs over the next eight to 10 years.

Although the treaty is expected to be signed at the Montreal meeting, some issues remain to be resolved. For example, the U.S. would like to see the treaty address the question of reducing production of halons, bromine-containing compounds used as fire retardants. There are also questions about how many producing countries must sign the treaty for it to take effect and possible trade restrictions against producing countries that do not sign the treaty.

Questions still remain, in fact, about what the U.S.'s position should be heading into this latest and perhaps final negotiating session. Early this summer reports surfaced that both the Department of Interior and the Office of Management & Budget questioned the draft treaty. Interior Secretary Donald Hodel, according to a spokesman, believed the draft treaty would be ineffective because too few countries and too few chemicals would be involved. And OMB questioned the costs and benefits of the draft treaty.



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Candidates in ACS fall election:
Their views and backgrounds Page 75
More scientific news from
ACS meeting in New Orleans

SEPTEMBER 21, 1987

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CHEMICAL & ENGINEERING

NEWS

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Paints & Coatings

Industry sales may top
last year's record Page 51

News of the Week

■ An atmosphere of reconciliation marks the efforts by Union Carbide and the Indian government to reach a settlement in Bhopal disaster-related litigation. **Page 6**

■ International pact to reduce the use of chlorofluorocarbons was signed last week in Montreal. **Page 7**

■ Hercules' sale of its stake in Himont to Montedison marks the culmination of 10-year strategy to rid itself of commodity-oriented petrochemical businesses. **Page 7**

■ Agent orange studies by Veterans Administration and Centers for Disease Control lead several Congressmen to call for probe of agencies' performance. **Page 8**

■ U.S. students perform less well in science tests than students from other countries, says international science study. **Page 8**

Cover: Du Pont top coat is applied in down-draft spray booth

Letters **4**

Concentrates

Business **11**

Government **16**

Science/Technology **31**

The Departments

ACS News **69**

Meetings **93**

People **110**

Newsclips **128**

Business

Montreal's petrochemical future improves as ongoing modernization revitalizes long-ailing ethylene producer Pétromont. **Page 13**

Government

From the ACS meeting: comparison of NIH funding of chemistry and other disciplines, science and technology centers initiative, environmental concerns in the chemical industry. Also, unauthorized test of genetically altered elm microorganisms begun in June is terminated. **Page 21**

Science

From the ACS meeting: structural clues to ceramic superconductivity, molecular modeling systems developments. Also, International Union of Pure & Applied Chemistry considers changes in its structure. **Page 33**

Education

Volunteer scientists enhance junior high school science and math; videodisks prove useful in teaching chemistry lab techniques. **Page 42**

Technology

From the meeting: Fragmentation fluorescence spectrometry techniques are among new tools for spectroscopic analyses. **Page 45**

Science Policy

Chemical society presidents discuss chemistry's deteriorating image, compare programs aimed at improving it. **Page 47**

ACS Election

Candidates for 1988 president-elect, directors-at-large, and directors for regions III and VI give views on ACS programs. **Page 75**



Product Report

Paints and coatings manufacturers meet technical challenges, deal with environmental dangers, and target end-use markets on their way to a possible record high in sales. **Page 51**

NIH Chemistry Funding Losing Ground Relative to Other Disciplines

Between 1977 and 1986 funding for chemical research increased only 110% while the overall NIH research budget was growing 300%

NEW ORLEANS

Although the National Institutes of Health has long been a major funding source for chemical research, the exact amount of chemistry funding has been difficult to determine because NIH doesn't break out research funding figures by disciplines. However, a recently conducted analysis of NIH's fiscal 1986 budget reveals a chemistry research funding total of almost \$140 million, according to Jerome G. Green, director of NIH's division of research grants. Green spoke at a symposium on issues in funding of chemical research and education, sponsored by the Division of Chemical Education.

The chemistry research funding amounted to 2.7% of NIH's total \$5.3 billion budget, Green says. In comparison, the National Science Foundation's chemistry division provided a total of \$85.8 million in fiscal 1986, whereas all NSF funding for programs involving at least some chemical research totaled \$198 million.

According to Green, the \$140 million in NIH chemistry funding includes \$135 million for 1153 research grants, \$2.6 million for 17 training grants, \$2.0 million for 109 graduate fellowships, and \$329,000 for three research contracts. Green's

analysis of NIH's chemistry research funding excludes funding for biochemical research. Factoring in those numbers would raise the total substantially.

Another way to look at chemical funding is to examine NIH research grants classified as chemistry and structural chemistry of biopolymers. These figures show 1985 funding for chemical research increased 19% from 1984 to \$134 million. The number of grants increased 8% to 1143. This growth rate slowed to almost a dead stop in 1986, with funding up 3% to \$138 million and number of grants up only 4. Of course, 1986 was the year of the 4.3% automatic, across-the-board budget cuts imposed by Congress in an effort to reduce the federal deficit.

Still that's not all there is to it. Green notes that NIH funding for chemistry research has been losing ground over the past decade compared with other disciplines such as medicine and biochemistry. Between 1977 and 1986 funding for chemical research grants increased

a bit more than 110% to \$138 million. During the same period NIH's overall research budget increased 300% to \$5.3 billion.

In part, Green attributes this less-than-stellar performance to requests for funding by chemistry departments not keeping pace with those from other departments engaged in biomedical research. He notes that competing research project applications from chemistry departments actually dropped from 851 applications requesting \$118 million in 1985 to 788 applications requesting \$117 million in 1986. The number of chemistry department requests isn't keeping pace in the current fiscal year either.

Green appears to be slightly puzzled by the declining number of applications. He points out that chemistry departments have an excellent success rate when it comes to competitive funding. In 1985 43% of the proposals were funded, in 1986 43.4%. The comparable success rates for all departments was 37.2% and 35.8%.

Competing chemistry grants hit \$138 million in 1986

Institutes	1986		1985		1984	
	Number	Amount (\$ millions)	Number	Amount (\$ millions)	Number	Amount (\$ millions)
General Medical Sciences	641	\$ 74.1	583	\$ 68.2	521	\$ 54.9
Cancer	196	24.0	210	23.2	199	21.2
Arthritis, Diabetes, Digestive & Kidney Diseases	67	9.1	97	12.5	105	11.6
Arthritis & Musculoskeletal & Skin Diseases ^a	23	2.9				
Heart, Lung & Blood	76	11.3	85	11.7	83	10.3
Allergy & Infectious Diseases	54	6.7	61	7.8	61	6.4
Neurological & Communicative Disorders & Stroke	33	3.9	38	4.7	37	3.7
Environmental Health Science	18	1.7	21	1.8	18	1.5
Other	39	4.6	48	4.4	35	3.7
TOTAL	1147	\$138.3	1143	\$134.3	1059	\$113.3

Note: Research does not include biochemistry, but does include structural chemistry of biopolymers. ^a Formed in 1986. Source: National Institutes of Health, Division of Research Grants

General Medical Sciences is major funding source for chemistry department research grants

\$ Thousands	Research grants ^a		Fellowships ^a	
	Number	Amount	Number	Amount
Institutes	1108	\$124,512	106	\$1974
General Medical Sciences	835	72,613	74	1352
Cancer	162	17,880	17	323
Heart, Lung & Blood	72	9,202	4	73
Diabetes, Digestive & Kidney Diseases	80	8,326	4	73
Allergy & Infectious Diseases	63	7,164	1	18
Neurological & Communicative Disorders & Stroke	26	2,626	1	20
Environmental Health Sciences	26	2,118	1	19
Eye	17	1,827	2	44
Arthritis & Musculoskeletal & Skin Diseases	8	1,000	—	—
Child Health & Human Development	10	950	2	52
Aging	6	496	—	—
Dental Research	3	310	—	—
Research Resources	45	10,391	—	—
Fogarty International Center	—	—	3	51
TOTAL	1153	\$134,903	109	\$2025

Note: Table includes both competing and noncompeting NIH awards. ^a Fiscal 1986. Source: National Institutes of Health, Division of Research Grants

Chemistry departments also do well when it comes to instrument funding. For example, in the Division of Research Resources' once-a-year competition for expensive (\$100,000 to \$300,000) instruments shared by at least three users, chemistry departments walked away with 18%, or \$5.6 million, of the total funds awarded in 1986; 28%, or \$8.8 million, in 1985; and 18%, or \$3.5 million, in 1984.

And there are other opportunities for funding. For researchers who are just starting out, five-year, nonrenewable awards provide up to \$350,000 for direct research costs in return for a commitment of 50% of a researcher's time and effort. Receipt dates for applications for the awards are Feb. 1, June 1, and Oct. 1.

In addition, once-a-year academic research enhancement awards are aimed at scientists in institutions that are not research-intensive, such as four-year colleges. Also available are the so-called area grants, mandated by Congress. Applications are submitted to and reviewed by the institutes in the normal manner but are funded from a specially appropriated fund that is running at about \$12 million per year.

There has been quite a bit of talk and fear in the chemical community recently that NIH is supporting less chemical research. But as Green concluded at the symposium, "You don't get it if you don't ask." He did admit, however, that a proposal has to be ranked very high in NIH's review process to get funded these days.

Janice Long, Washington

NSF to seek science center proposals

NEW ORLEANS

The National Science Foundation expects to issue a program announcement of its new science and technology centers initiative this month. Kenneth G. Hancock, acting director of the chemistry division, told attendees at the Division of Chemical Education's symposium on issues in funding of chemical research and new education. NSF may devote up to \$35 million to the initiative, which, he emphasizes, will be focused on basic research.

To be successful a proposal for a science and technology center will have to have a unifying intellectual theme, Hancock explains. It has to be more than just a collection of people who want funding for their individual research projects. There needs to be a close correlation between the planned research and a center's size, structure, and organization. The center must also have a strong educational component and be linked to other sectors of society, such as state and/or local governments, private industry, or the national laboratories. Matching funds, although encouraged, are not necessary, he adds.

There will be a single competition among proposals from all fields for the centers and an institution may submit multiple proposals on multiple topics or a single proposal on a single topic. The chemistry division will review the proposals that fall under its research areas, Hancock says, adding that the "review process is going to be awesome from start to finish" and will culminate with site visits for those on the short list for final funding.

The centers will have a finite life, Hancock explains. NSF will make an initial five-year funding commitment to a center. There will be an intensive review of the center's operations and accomplishments after three years, and, if all has gone very well, Hancock says, an additional five-year commitment could be made.

For those not quite ready to submit a full-fledged proposal, a university has the option of obtaining a \$35,000 planning grant, which must be matched with an institution's own funds. Letters of intent will have to be submitted by Nov. 15. Formal center proposals will be due by Jan. 15, 1988, with planning grant proposals due Feb. 1.

Asked if he could provide some hints on the type of research NSF thought would be suitable for a center, Hancock replied: "I can, but I won't. I've learned that when the federal government speaks, everybody listens. We don't want to dictate the proposals. Everyone will have to use their own ingenuity in putting together the proposals."

Janice Long, Washington

Paint Sales May Top 1986 High

Marc S. Reisch, C&EN New York

Though the pace of the paint and coatings business seems to have slowed in the first half of 1987, it nevertheless promises to be a year in which paint makers will finally ship \$10 billion or more in paint.

Paint is a competitive business in which small producers have gone out of business and other producers have been absorbed by larger ones—some of them global paint producers such as Imperial Chemical Industries, BASF, and Du Pont. Yet the competition does not seem to have hurt the business. The U.S., it seems, is awash in paint.

According to statistics cited in C&EN's industry survey article beginning on the next page, paint makers shipped 967 million gal of paints and coatings in 1986 worth some \$9.68 billion. Though shipments may be down this year, their overall value may be up, Department of Commerce figures show. This indicates that the market is strong enough to support a little extra margin for manufacturers, allowing them to pass along some of their increased raw material costs.

But competition among paint manufacturers remains keen. Despite slow growth in some segments

such as automotive refinishing, examined in a section of this report beginning on page 56, manufacturers are meeting technical challenges. Some paint makers are developing new generation finishes to compete in durability and drying time with isocyanate-cured enamel coatings. Many are coming to grips with the environmental dangers posed by volatile organic compounds released when solvent paint formulations dry, even though the problem has not really affected auto body shops across the country yet.

The coil-coating market, another

segment of the paint business examined in a section beginning on page 66, is a business that some observers may deem a lackluster, no-growth paint market. It is an industry bereft of a major end-use market: as auto makers resort more to in-house metal priming systems, there is less need for the zinc-rich coated steel for which Detroit once had a huge appetite. But coil-coating industry executives and their paint suppliers are exhibiting imagination and are targeting end-use markets that are here now, such as appliances.



Shipments may decline, but value may surpass \$10 billion this year



Civic center with steel panels coated with Glidden's fluorocarbon paint

Last year was a banner year for paint production. U.S. manufacturers shipped a record 967 million gal of paint and coatings worth \$9.68 billion, according to the Department of Commerce. The 3% growth in shipments in 1986 and the 5.4% growth in the value of those shipments in 1986 is no small accom-

plishment given the large size of the paint and coatings market.

There is more than a little life left in a business that has been characterized as mature, highly cyclical, and largely dependent on volume markets. Because of a continuing ebullient economy, 1986 shipments increased in every category served

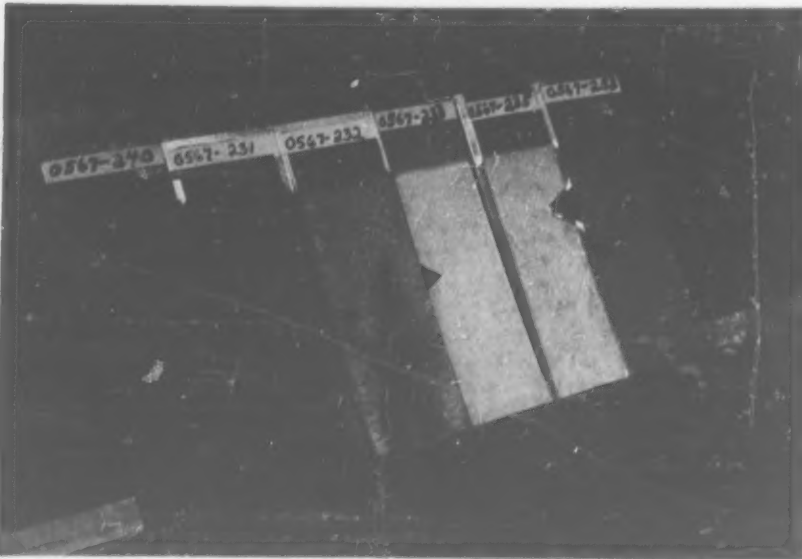
by paint and coatings manufacturers: architectural coatings, product coatings sold to original equipment manufacturers (OEM), and special-purpose coatings.

Preliminary government figures show, however, that the pace of U.S. production slowed in the first half of 1987. Real gross national product declined from an annual growth rate of 4.4% for the first quarter to 2.5% in the second quarter. The slowdown has already affected 1987 paint and coatings shipments. Unless the economy along with the paint industry experiences an unusually strong second half, the industry will not only be hard pressed to match last year's shipment figures, but also will be unlikely to surpass the billion-gallon shipment mark.

For the first six months of this year, shipments declined 2.7% to 509 million gal compared with the first six months of 1986. Shipments of architectural coatings, at 257 million gal for the first six months of 1987, remained virtually unchanged from the same period in 1986, whereas those of product coatings increased a slim 2.4% to 179 million gal. And shipments of special-purpose coatings slid 20% to 72 million gal.

However, the value of paint shipments in the first six months increased 6.8% to \$5.3 billion, compared with the like period in 1986. And at this rate of increase, they may finally crack the elusive \$10 billion mark. The value of architectural coatings rose 4.4% to \$2.2 billion, and product coatings increased in value an impressive 13% to \$2.0 billion. Special-purpose coatings grew a marginal 1.1% to \$1.0 billion.

This year will not be so good a year as 1986 for the paint industry, forecasts Business Trend Analysts (BTA), Commack, N.Y., a market research firm. However, it does predict an increase in the value of shipments. In a study of the paint and coatings industry it intends to publish at the end of this month, the Long Island-headquartered consultant looks for a 4.5% increase in 1987 sales of paint and coatings, but notes that "slow price gains in the architectural coatings segment, coupled with slackening durable

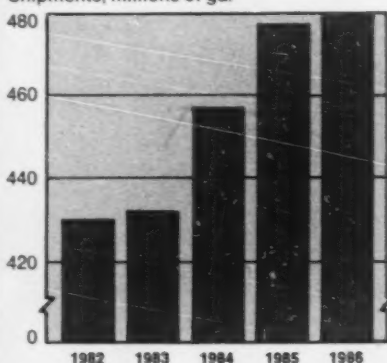


Panels coated with different paints that have been exposed for 16 years in subtropical Florida at a 45° angle facing south. Top 2 inches or so of the panels were covered by the rack and represent the original colors of the panels. Blue panels on each end, coated with Glidden fluorocarbon paints, show how such coatings resist color change when exposed to hot sun

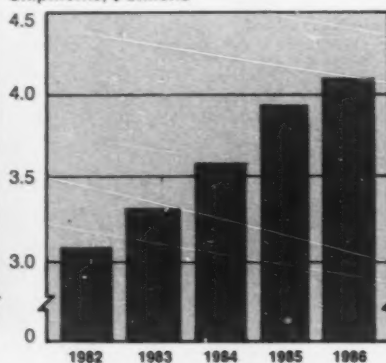
Shipments rise in all categories, but prices up only for architectural coatings

Architectural coatings

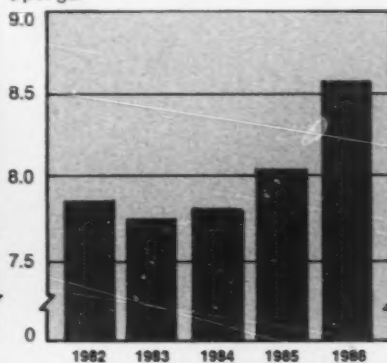
Shipments, millions of gal



Shipments, \$ billions

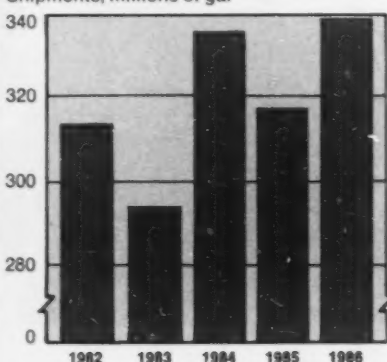


\$ per gal

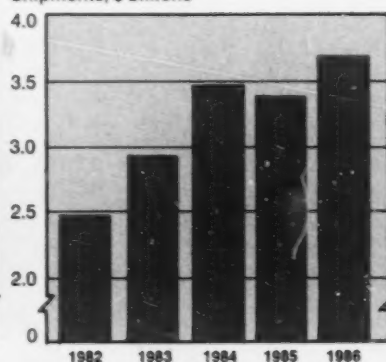


Product coatings*

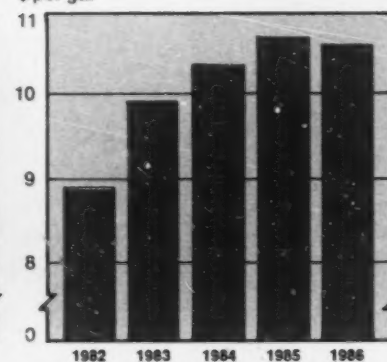
Shipments, millions of gal



Shipments, \$ billions

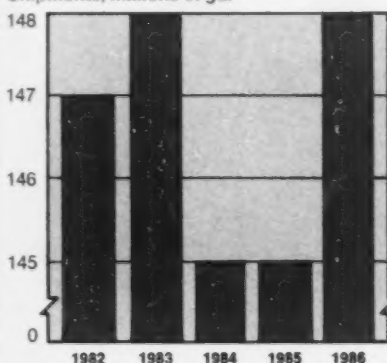


\$ per gal

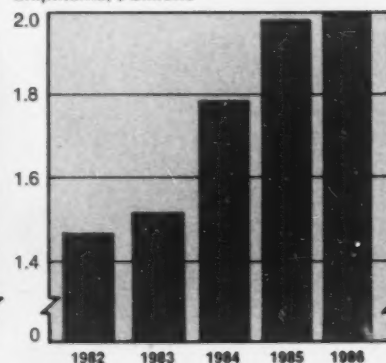


Special-purpose coatings

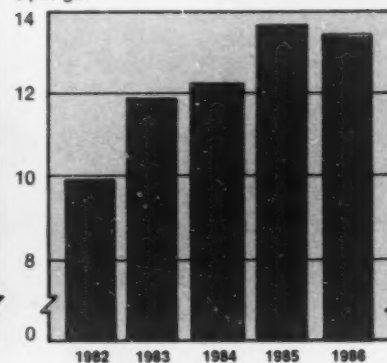
Shipments, millions of gal



Shipments, \$ billions



\$ per gal



* Original equipment manufacturers. Source: Bureau of the Census

goods output, portend a lackluster 1987 market performance."

A 1986 profile of the industry based on Bureau of the Census figures shows that architectural coatings, which include both interior and exterior house paints, continue to make up almost half of all paint

sold in the U.S. Product coatings for the original equipment market, which includes automotive and appliance coatings, accounts for some 35% of U.S. paint volume. And special-purpose coatings comprise about 15% of total paint shipments. That category includes large-volume

maintenance items, automotive refinishing, and coil coatings.

Shipments of architectural coatings in 1986 increased marginally from 1985 to 480 million gal. However, the value of shipments continued to improve, up 7.6% last year to \$4.12 billion, and the unit price

Three main paint categories break down this way

Architectural coatings

Exterior house paints
Interior house paints
Undercoaters, primers & sealers
Varnishes
Stains

Product coatings*

Wood furniture & fixtures
Automotive
Metal containers
Machinery & equipment
Factory-finished wood
Metal furniture & fixtures
Sheet, strip & coil
Nonautomotive transportation
Appliances
Electrical insulation

Marine

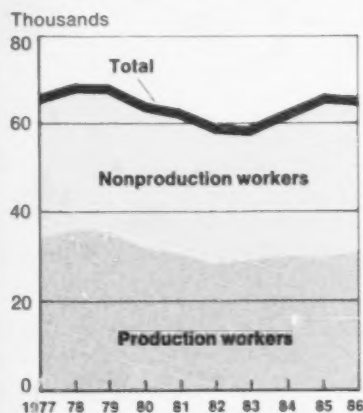
Film, paper & foil
Pipe
Toys & sporting goods
Miscellaneous consumer & industrial products

Special-purpose coatings

Automotive & machinery refinishing
High-performance maintenance
Traffic paint
Bridge maintenance
Aerosols
Swimming pool coatings
Arts & crafts
Metallic coatings
Multicolored coatings

* Original equipment manufacturers. Source: SRI International

Paint production worker employment rose in 1986



Source: Department of Labor

per gal increased 6.7% to \$8.56. Despite its reputation as a lackluster category, architectural coatings was the only segment to show an increase both in shipments and value in 1986. Analysts suggest that the decline in interest rates along with a pickup in housing starts has spurred demand for more single family homes for the baby boomers, and that this trend will continue into 1987.

Product coatings shipments for the OEM sector increased 6.9% in 1986 to 339 million gal. Though the value of product coatings shipments rose 5.6% last year from 1985, unit price declined 1.3% to \$16.53 per gal.

Similarly, special-purpose coatings shipments and total value of those

shipments increased, but unit value declined in 1986. According to the government figures, special-purpose coatings shipments increased 2.1% to 148 million gal in 1986, and the value of those shipments increased 1.0% over 1985. However, unit price declined 1% to \$13.47.

Areas such as water treatment equipment and hazardous waste treatment equipment will lead an increase in demand for paint, according to Jay R. Willner, president of WEH Corp., San Francisco-based market analyst concentrating on certain industrial and special-purpose coatings markets. The market for bridge and highway coatings also likely will show a strong increase in demand, says Willner, as many of the nation's busiest byways are in serious need of attention. Higher-priced, long-lasting coating systems will be the answer, he adds.

Willner says that demand for marine coatings is down as new marine construction in this country is "dead," and offshore oil drilling activities are flat.

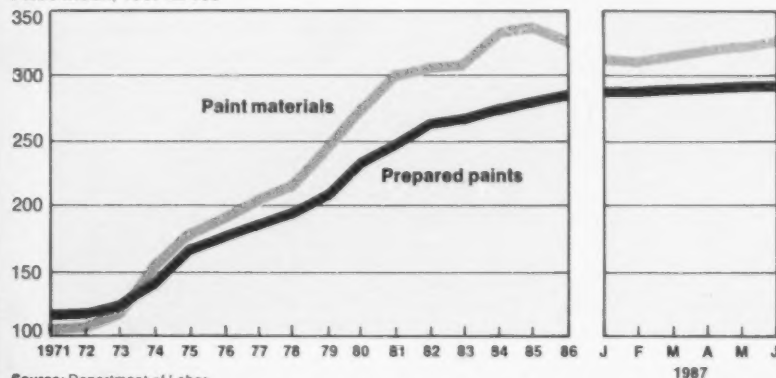
One major trend in the maintenance coatings business is a movement to farm out the maintenance of large petroleum refining, petrochemical, and pulp and paper plants to specialists. In this case a supplier takes responsibility for assuring a plant is maintained according to ordinances, sand blasting and coating equipment and plant as necessary, Willner says. Leaders in this new marketing approach to plant coatings and maintenance include Du Pont and PPG Industries, he says.

Overall, the paint business remains a highly competitive one despite the litany of mergers and acquisitions that have tended to concentrate it into fewer hands. The past few years have seen a number of changes. For instance, Imperial Chemical Industries purchased Glidden, BASF purchased Inmont, Du Pont sold its Lucite line of paints to Clorox, and Valspar bought Mobil's U.S. and Canadian coatings operations.

Despite the numbers of purchases and acquisitions, industry sources report there still are about 1000 paint manufacturers in the U.S. (down from about 1500 in 1963, says one

Gap is widening again between raw material, paint prices

Price index, 1967 = 100



Source: Department of Labor

source). Because of the competition, product advances do not readily translate into huge profits because competitors quickly catch up with advances of their own. Pricing is frequently the manufacturer's key to a larger share of the market and thus greater profits. And in a bid for greater share of market, manufacturers have tempered price increases even though raw material costs are increasing much faster.

According to the Department of Labor, price indexes covering both paint materials and prepared paints for the first six months of 1987 show that, after a brief hiatus in 1986, prices of raw materials continue to increase faster than prices of prepared paint. The index for paint material prices rose 5.4% from January to June 1987 to 332.5 (1967 = 100), reflecting recent increases in polymers and runups in the price for titanium dioxide. However, during the same time, the index of prepared paint prices has increased only 0.09% to 284.1 (1967 = 100).

In the past, the gap between the two indexes widened steadily as manufacturers in a competitive market held prices below their increases in raw material costs. In 1979, the index for raw material prices swung up decisively and manufacturers again held prepared paint prices pretty much in check. For 1979, the index for raw material prices increased 13% from the previous year to 241.2, whereas that for prepared paint prices rose only 5.7% to 204.4.

Even though steady raw material price increases between 1980 and 1985 averaged 4.1% and prepared paint price increases during the same period averaged only 3.3%, the raw material price index dropped in 1986 to 318, down 4.9% from the previous year. Prepared paints manufacturers took advantage of the improved situation to take a modest increase. Last year the prepared price index increased 1.6% to 381.2.

The dip in raw materials prices in 1986, explains Business Trend Analysts (BTA), stems from the decline in the price of crude oil from which paint resins, solvents, linseed oil, and tall oil are derived. The drop in raw materials prices did not bring about a wave of competitive price cuts, BTA adds, because of increased

industry R&D expenditures. These increased expenditures were mandated by government regulation in the disposal of solvent waste and pollution control.

To their credit, paint manufacturers have been able to produce more paint as the level of employment has slowly declined. According to Department of Labor statistics, the total number of production and nonproduction paint industry workers declined 3.9% to 63,400 between 1977 and 1986. The number of workers in the industry was the same in 1986 when manufacturers produced

967 million gal of paint as in 1981 when paint manufacturers made only 870 million gal.

From 1977 to 1986, the number of nonproduction employees of paint firms rose 5.8% to 32,700 as the companies boosted their marketing efforts. Employment of nonproduction workers peaked in 1985 at 33,600.

The industry achieved its record 1986 output with 2.7% fewer nonproduction workers than in 1985. A 2.3% rise in production worker employment to 30,700 helped it realize a 3% improvement in shipments in 1986 to 967 million gal.

Automotive refinishing poses huge and changing market

By one estimate, paint and auto body shops do an astounding \$10 billion in collision repair and refinish work annually. But this business is growing only 1 to 2% annually, most industry observers say.

Few paint companies heavily involved in automotive paints, however, can ignore this enormous market, which in 1986 consumed some 66 million gal of paints, about 45% of the category defined as special-purpose coatings by the Department of Commerce. These paints had a value of about \$895 million.

The automotive refinish paint in-

dustry itself is slowly changing. First, paint makers have introduced formulations and refinish systems compatible with the latest base-coat/clear-coat technology that is becoming more prevalent among original equipment manufacturers (OEM). Second, many manufacturers have only recently announced isocyanate-free paint formulations that promise the performance of isocyanate-containing paints. Third, although emissions of volatile organic compounds are mostly a concern at the OEM level, paint makers are thinking now about ways to address the problem at auto body shops if and when they become an issue. (Volatile organic compounds are pollutants that may foul the air as solvent paint formulations dry.)

Statistics on the automotive refinish market generally include truck and bus repair as well. However, passenger cars account for 75% of sales in this market, industry sources indicate. Major suppliers to automotive refinish jobbers and ultimately to the auto body shops include primary OEM suppliers PPG Industries, Du Pont, and the Inmont division of BASF. Other paint makers, such as Sherwin-Williams and the Sikkens division of Akzo Coatings, also have secured niches in the automotive refinish market.

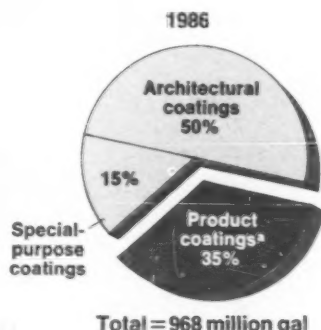
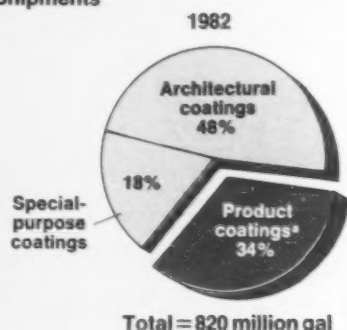
All these suppliers are watching closely to see if U.K.-based Imperial Chemical Industries, which recent-



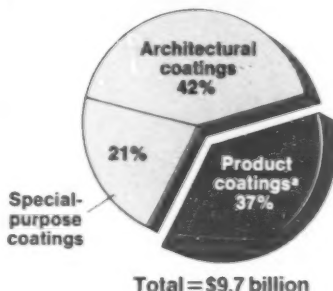
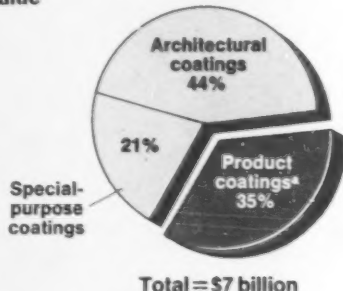
Harrick: urethane paint use will grow

Architectural coatings still lead paint shipments and value, but product coatings grow in both categories

Shipments



Value



* Original equipment manufacturers. Source: Bureau of the Census

ly purchased U.S. paint producer Glidden, will attempt to enter both the OEM and automotive refinish markets in the U.S. ICI is a major European supplier of both OEM and automotive refinish paints.

A major force in the automotive refinish market by virtue of its position as a supplier of polyurethane raw materials, including the polyisocyanate quick-curing additives, is Mobay. According to G. Thomas Harrick, vice president and general manager of Mobay's coatings division, most major paint companies use Mobay's Desmodur polyisocyanate ingredient in some of their formulations, primarily to provide a harder finish but also to speed drying and reduce dust pickup, an almost universal problem in the auto body shop. Harrick estimates that urethane paints make up half of all automotive refinishing formulations.

Urethane paint systems offer numerous advantages, he points out, especially the two-component system in which the polyisocyanate ingredient is added to the paint for-

mula just before spraying a vehicle. Urethane coatings, he says, improve the final appearance of a painted vehicle because they provide excellent gloss, distinctness of image, and durability. In addition, they resist chipping and do not readily etch and break down.

However, polyisocyanates require care in handling because fumes of polyisocyanate-modified acrylic paints may be harmful if a painter inhales them. The problem, says Harrick, is that of the 70,000 automotive repair shops he estimates are operating in the U.S., there are many small shops that may not take adequate precautions to protect workers. All painters should know that "it is not healthy to breathe polyisocyanate-modified paints or any other resins and solvents," he says.

Painters must wear protective breathing equipment, Harrick points out. He also says that Mobay offers a free safety monitoring service and will provide body shops with a written report on how and where ventilation must be improved.

Despite the recent introduction

of new automotive refinishing formulations from Du Pont and PPG and a scheduled introduction of such formulations next year from the Inmont division of BASF claiming urethane performance without the polyisocyanate ingredient, Harrick is confident the market for polyurethanes will expand. "From the samples we have of what's out there, we don't feel that any new products on the market match the performance of urethane paints."

Overall, says Harrick, the automotive market has been "a consistent business. It's not a business that necessarily grows each year. It may have even declined some in recent years." He sees three major reasons for the decline. First, the number of smaller cars, with consequently less surface to cover, has increased. Second, more insurance companies are "totaling" cars involved in accidents because of sky-high repair costs. Third, paint supplied at the OEM level resists corrosion today better than ever before, and, as a result, fewer people are bringing cars in for cosmetic repairs.

Still, Harrick expects urethane paints use to grow as a percentage of both OEM and the automotive refinish business because, he says, they perform better than the alternatives. More OEMs will use urethane paints as the clear-coat component in the new base-color-coat/clear-cover-coat systems major manufacturers are now phasing in. And as more plastic components are used on new vehicles, the two-component urethane systems will cover the plastics as well as the traditional metal body components.

Though differing with Harrick's views of the comparison of urethane-based with nonisocyanate paint, the views of H. James Robinson, vice president and general manager of automotive refinishing for the Inmont division of BASF, do jibe with Harrick's overall assessment of the automotive refinishing business. "I can't be real optimistic about growth in the automotive refinishing business, but I am confident that we will be holding our own share of the market," says Robinson.

Robinson also cites the improved corrosion resistance of coatings used

Product Report

by OEMs as a reason for the drop-off in corrosion repairs. "It is partly due to the cathodic electrical priming coat we and our competitors have supplied to the automotive industry. That has affected our automotive paint business, and overall I guess it's good," he says.

Currently the automotive refinishing business is consolidating, Robinson says. Like European body shops, American shops will become more sophisticated, requiring more expensive equipment such as downdraft booths and ovens to do a good job. And as the OEM market uses more base-coat/clear-coat technology, the refinish market will follow and will need better equipment to do the job, he says.

PPG sees its participation in the automotive refinish market as an extension of its business in the OEM market. "It's a global business for us," says Mike Sack, manager of customer services for PPG's coatings and resins division. "We're in it for the long haul," he adds.

Like its competitors, PPG supplies a full line of acrylic lacquers, alkyd and acrylic enamels, vinyls, and acrylic urethane products. But, says Sack, two-step base-coat/clear-coat



Automotive spray painters must wear protective breathing equipment

technology is growing in automotive refinishing, following the trend in OEM.

Though isocyanate-containing urethane finishes are not for general consumer use because of their toxicity, Sack says they have a definite place in the automotive refinishing market. "They are a fact of life," he says, though "they have been given a bad rap. They are safe if used properly."

PPG, says Sack, wants to deal with professional painters. To help them use its products effectively, the company, like its competitors, runs training facilities. Two PPG training facilities are already in place in Delaware, Ohio, and Flint, Mich., aimed at educating PPG sales representatives and staff distributors, as well as body shop and fleet maintenance personnel. Two more facilities, to be staffed by PPG trainers, are on the drawing boards for New Jersey and the Los Angeles area, he says. In an effort to garner a larger share of the market, PPG also plans satellite classrooms at 10 to 15 other locations.

PPG has been at the forefront, Sack says, in developing a new generation of nonisocyanate-containing paints that deliver the same performance as an isocyanate-containing paint. The company's NCT clear coat applied over PPG's nonisocyanate Deltron base coat was introduced late in 1986 and, though it costs more than isocyanate-containing paints, has "done a remarkable job penetrating the market," claims Sack.

Problems with volatile organic emissions, an issue particularly on the OEM level, is not a big problem yet for auto body shops, Sack says. The typical repair does not require a lot of paint. PPG has low-volatility systems available now, he says, following on the growing demand for paint in the OEM market with low-volatility compounds.

Gene A. Gardner, refinishes director at Du Pont, says that the refinish business grows in pace with the overall economy. The only downturn occurred during the Arab oil embargo when people did not drive their cars as much. As a result, work on collision repairs, accounting for 90% of all paint refin-

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Product Report

ish work, was down. Gardner says that only 10% of refinishing paint sales are due to people who want to make their older car look new, or dealers who repaint a car to improve its resale value.

Du Pont is also sensitive to concerns that isocyanate-containing paints may pose a health hazard if they are used improperly, Gardner says. When they are used properly they work well, he stresses, and isocyanate-containing paints now make up 50% of Du Pont's automotive refinish paint sales. Du Pont does offer a nonisocyanate-containing paint—it introduced its Cronar paint system in January this year, Gardner says.

Although Du Pont does supply waterborne base coats for OEM markets, Gardner thinks it will be several years before waterborne technology may be used in the refinish business. Temperature and humidity conditions can be rigidly controlled at the OEM level. But the majority of body shops in the U.S. do not now have the advanced, expensive spray booths and ovens to allow them the precise control over paint application and drying conditions. Lacquer and enamel refinish

systems now widely used in the refinishing business can be used on spot repairs and still match the new OEM paint systems.

Du Pont also provides training centers for its jobber salesmen in Troy, Mich., Atlanta, and Los Angeles. Du Pont has 28 training centers located at its warehouses across the U.S. providing body shop personnel with instructions on safe use, color matching, and other facets of paint preparation and refinish.

Like others in the automotive refinish business, Du Pont is watching for the possible entry of ICI into the U.S. automotive refinish business. Gardner notes that Du Pont actively competes with ICI in Europe and thinks it may just be a matter of time before ICI enters the U.S. market via Glidden. However, he says, "We're familiar with what they do and how they do it."

Indeed, ICI will be actively examining the possibility of entering the automotive paint business in the U.S. via Glidden, says Brian S. Codling, ICI Autocolour's general manager. Codling claims that ICI is the largest automotive refinishing paint supplier outside the U.S. "If we see the right opportunity, we will get



Automotive market consumed about \$895 million worth of paint last year

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in the U.S. market," he says. "We wouldn't just jump in. We respect Du Pont, PPG, Inmont, and the others already there."

In Europe, there has been a reduction in the number of small independent body shops, says Codling. Owners of surviving shops have invested in ovens, spray booths, and other expensive advanced equipment so they can refinish cars more quickly and get the maximum return on their investment, he says. This is particularly true in larger cities where there are more chain-type operations in the auto body repair market than there were a few years earlier.

It is also in the larger cities, particularly in West Germany, that local authorities are concerned about volatile organic emissions, says Codling. As a result, he thinks the market will be ripe for ICI's Aquabase waterborne base-coat system between 1990 and 1992.

Noting the current trend among paint makers in the U.S. to launch nonisocyanate-containing refinishing paints, Codling says that ICI launched such a paint in the European market a few years ago. "They weren't as good as two-pack acrylics," he says flatly. He adds that "if you are going for a fast-curing paint you need a rapid chemical reaction, and as such that will pose a danger to humans." ICI, he says, still professes the use of isocyanate-cured paint systems while emphasizing the safe applications of those paints.

Sikkens, a division of the Dutch chemical company Akzo, competes in Europe with ICI and others in the automotive OEM and refinishes market. In the U.S., the company operates as a division of Akzo Coatings America and supplies the automotive refinishes market. Sikkens has been a player in the U.S. automotive paint market only since 1980, says Gerald J. Burt, Sikkens' vice president of operations.

Sikkens' most recent U.S. product is an isocyanate-free, fast-drying paint called Autonova. Introduced in April this year, the paint offers the same quality finish as an acrylic urethane, Burt says. He terms the new Autonova product "more user friendly" than acrylic urethanes. Autonova is not being offered in

Europe, Burt says, because most European shops, 90% of which are equipped with downdraft spray booths, are better equipped to handle isocyanate-containing paint formulations.

At present, he says, Sikkens' largest selling product is an isocyanate-containing acrylic urethane paint. But, he adds, "We're concerned about the isocyanate issue, both in the U.S. and in Europe." However, in the U.S., "people think they are invincible, even after all the education about isocyanates. Major body shop managers at dealerships don't even know what isocyanates are and what precautions are necessary when they are being used."

Unlike its competitors in the U.S., Sikkens does not supply factory-packed colors to match OEM paint formulations, Burt says. A carousel color-matching machine, with 80 different toners mounted in place, "can match any OEM color from an Alfa Romeo to a Zag, whatever that is," he says. Paints also can be mixed only in the actual quantities needed, thus producing a savings in materials costs, where paint costs to repair shops can run as high as \$40 a gal for the better-quality paints.

Given all the concern with isocyanate formulations, one paint industry supplier, Monsanto, is developing proprietary new technology to displace isocyanates. The company will discuss the development of a "nonamino condensation curing product" for the paint industry at the Paint Show in Dallas in October, according to an industry source.

As a supplier of acrylic polyols to the automotive refinish industry with an interest in new product developments, Rohm & Haas believes that new curing technology introduced by Du Pont, PPG, and Sikkens is the wave of the future. "Water-based automotive refinishing paint technology is a long way down the road," says Dave M. Watson, Rohm & Haas' market manager for solvent-borne industrial coatings. And though the trend is for formulators to move away from alkyd acrylic modified urethanes, it still won't affect the demand for alkyds or Rohm & Haas' own Acryloid acrylics, he adds.

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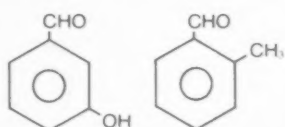
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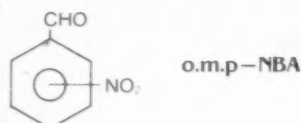
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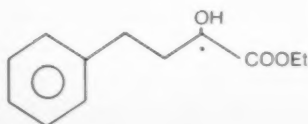
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Product Report

Coil coaters look for growth in appliance, metal furniture markets

Faced with losses in the transportation market, paint makers supplying coil coatings are basing their hopes on the appliance market and are trying to develop uses for the coatings in office furniture.

Following a high in 1984, shipments of weldable zinc-rich coil-coated steel dropped again last year. According to Jeff Back, project manager with market research firm Charles H. Kline & Co., auto makers have replaced zinc-rich weldable coatings with newer, in-plant cathodic electrical priming systems. As Back sees it, "Coil coaters are scrambling to replace the business. It will be a struggle for them." Though they are "targeting the appliance business, I suspect it will be difficult for them to replace the business they've lost on the automotive side," he says.

Between 1984 and 1986, the overall market for coil-coated steel and aluminum declined as shipments fell 22% to 7.68 billion lb, statistics from the National Coil Coaters Association (NCCA) show. The market for coil-coated steel for the transportation market alone fell 26% during the same period.

Back's skepticism that the appliance market can take up the slack is supported by NCCA statistics. Shipments of coil-coated steel for appli-

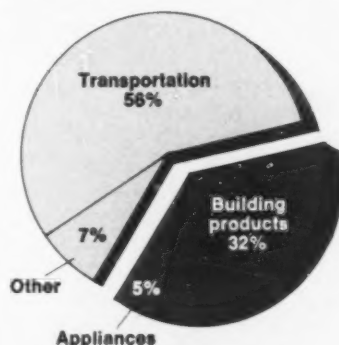
ances grew just 12% between 1984 and 1986 to 266 million lb. As a percent of overall shipments of steel coil-coatings, appliances' share increased from 4.7% in 1984 to 6.4% last year.

But Robert W. Moorman, market manager for coil-extrusion coatings at Glidden, envisions that new paint technology will help coil coaters regain share for wide sheet coil-coated steel and will help coil coatings further penetrate the appliance and office furniture market. One coil coater already has provided preprimed steel coil with a primer coat that is flexible enough to maintain its adhesion and integrity during stamping of metal body panels, Moorman says.

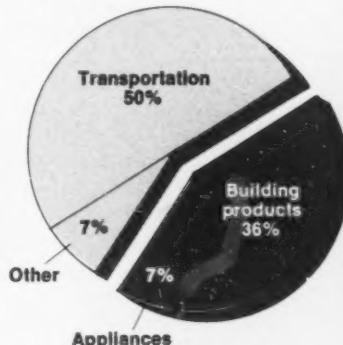
Experiments in stamping preprimed and painted coil-coated steel hoods and decks have been carried out, and such applications could be a reality in automotive manufacturing "in the early 1990s if manufacturers would embrace the technology," Moorman adds. Though coil-coated parts are already widely used under vehicle hoods, getting coil coatings back on vehicle exteriors "is a major target for the future," said Moorman.

The increasing use of coil-coated parts by appliance makers is also encouraging, Moorman says. "Ap-

As transportation market for coil coatings shrinks, building products and appliances markets grow



Total 1984 = 5.01 billion lb

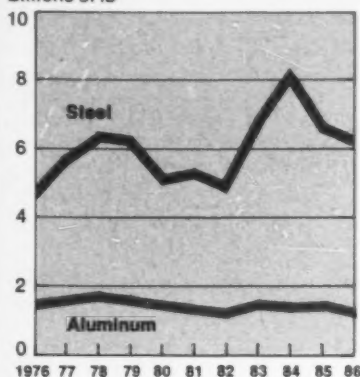


Total 1986 = 4.19 billion lb

Note: Totals include Canada and Mexico, and are based on actual tonnage supplied by reporting companies.
Source: National Coil Coaters Association

Shipments of coil-coated steel, aluminum have fallen

Billions of lb



Note: Figures include Canada and Mexico.
Source: National Coil Coaters Association

pliance manufacturers do not necessarily want to be painters," he says. The government's clamping down on emissions of volatile organic compounds also will provide additional incentive for appliance makers to look to coil coaters for pre-painted parts.

In addition, metal office furniture, now painted by the manufacturer, could be made of precoated steel, Moorman says. He sees a market developing for filing cabinets, desks, credenzas, and partitions, all of coil-coated steel. Moorman thinks this market will materialize because it's a more efficient way to produce metal furniture. Coil-coating transfer of paint to metal is 97% efficient, he says, and requires one sixth of the curing energy required to bake dry a metal cabinet or desk because coil coatings are processed on a flat continuous line.

Steel furniture producers, like appliance manufacturers, would not have any significant emission problems with volatile organic compounds. Coil coaters generally operate in plants that burn off solvent evaporated from coils in their ovens to provide additional curing energy as well as heat for plant facilities.

Although steel furniture is now welded together for assembly, Moorman says, new systems are being developed to put together coil-coated furniture with either adhesives, clips, or bolts. Adhesives, such

as epoxies, polybutenes, and polysulfides, offer the most promise for metal furniture assembly because they are the least labor- and capital-intensive.

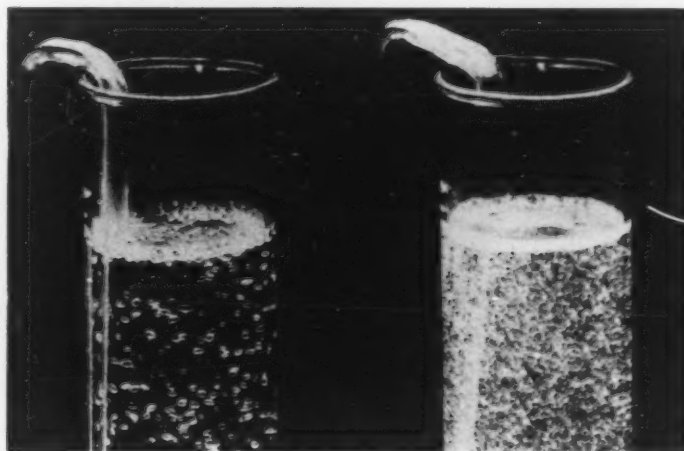
Industry analyst Back is more bullish about prospects for coil-coated aluminum than for steel. He sees good to modest growth ahead for this smaller segment of the coil-coating business, translating into steady business for paint suppliers. The market has stabilized, he believes, because vinyl building siding has secured its niche and probably will not gain a larger share of the market than it already has. Aluminum beverage cans, says Back, are a stable business and a strong market for aluminum minislat window blinds also is likely to promote growth in the aluminum coil-coatings market.

George F. Detrick, building products market manager for Rohm & Haas, agrees with Back that vinyl siding sales will not displace any

more aluminum siding. Because that business has consolidated, Rohm & Haas says it is doing more business as a merchant supplier providing paint formulators active in this business with its Rhoplex acrylic emulsions.

The acrylic emulsions used in coating aluminum are waterborne, and so there is very little concern about volatile organic emissions, says Detrick. "The industry switched to waterborne coatings a while ago. Aluminum coil coaters found they could readily obtain the durability they required from waterborne systems. Only some toll coil coaters prefer solvent-based aluminum coating systems because they claim they can change colors and clean up their equipment for the change more quickly."

Waterborne primers for aluminum coils are making inroads, says Detrick, and they are suitable for toll coaters because a standard primer color can be used under any num-



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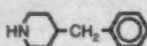
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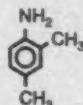
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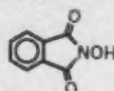
4-Benzylpiperidine



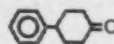
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Product Report

ber of different topcoat colors. In cases in which coaters may object to using waterborne coatings for fear they may experience equipment corrosion problems and coil-covering flaws, some engineering changes in the equipment may be necessary, he says. "Roller pins and reservoirs for waterborne coatings must be designed differently than for machinery running solvent systems," he explains.

Another supplier to coil coatings paint formulators, Monsanto Chemical, is bullish on growth in coil-coating applications in the appliance market and for steel office furniture. "Precoating steel for the appliance and steel furniture market will help manufacturers reduce their costs and turnaround time and also allow them to produce a more uniform product," says Michael W. Berezo, amino resins business manager of Monsanto Chemical's resin division.

Monsanto supplies high-solids methylated melamines used as crosslinking agents in paint formulations. Its Resimine 747 for solvent-based formulas and 745 for waterborne systems "are our bread and butter crosslinkers," he says. Crosslinking agents aid the curing process as painted coils pass through drying ovens.

Monsanto has the capability to tailor make a crosslinking agent for coil coatings aimed at the appliance and steel furniture markets, Berezo points out. A good crosslinking agent for these applications would help in developing coatings with the right balance of properties. What the user wants, he says, is a hard film with good integrity. However, the film must be flexible enough to bend into form and still adhere solidly to the substrate. The film also must resist oil and grease.

The company introduced a new methylated melamine crosslinking agent, Resimine 797, last year. It aids the rapid drying of baked coatings but at a lower temperature than can be achieved with other methylated melamine crosslinking agents in Monsanto's line, Berezo says. Coil coatings using the new additive may cure at lower temperatures to achieve film quality similar to that from Resimine 747 and 745, he claims. □

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Hydrothermal Crystallization

Page 30

News of the Week

■ ICI sells Stauffer Chemical basic chemicals operations to Rhône-Poulenc for \$522 million. Page 4

■ Test firing of space shuttle's redesigned solid rocket booster is a success. Page 5

■ New six-part science series, "The Ring of Truth," begins on PBS on Oct. 2. Page 5

■ House subcommittee hearing on AIDS elicits requests for funding, compassionate treatment. Page 5

■ Fraud in research was the topic of conference held by scientists, lawyers, and government and university officials. Page 6

■ House knocks \$50 million off NSF's proposed budget for fiscal 1988. Page 6

Cover: Two large hydrothermal autoclaves used for growing crystals at AT&T Bell Laboratories are examined by Robert A. Laudise (left) and Anthony J. Caporaso

Letters	2
Editor's Page	3
Concentrates	
Business	7
Government	12
Science/Technology	20
The Departments	
ACS News	44
Meetings	48
Newsclips	72

Business

Increased demand for ethylene, coupled with tightening supplies, allows producers to raise prices about 15%. Page 9

Makers of chlorinated solvents face dropping demand owing to pressure from regulatory and environmental groups. Page 11

Government

Schools—from universities to small town systems—are learning how to use and dispose of hazardous chemicals safely. Page 15

Proposed space station faces technological, financial, and management problems before it gets off the ground. Page 16

Interagency task force claims acid rain isn't harmful; environmentalists cry "propaganda" and Canada terms it "voodoo science." Page 18

Science

Cornell scientists use gas chromatography technique, and human volunteer sniffers, to quantitate odor-active substances in food. Page 21

A wide variety of alkane C-H bonds can now be activated by direct intermolecular insertion. Page 23

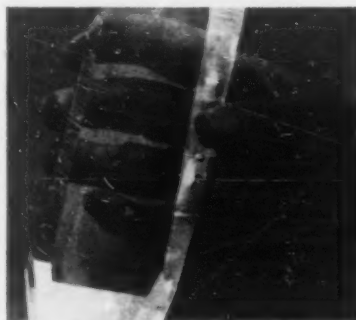
National Academy of Sciences report on superconductivity at high temperatures targets eight key research areas. Page 23

Education

Problems of Ph.D. candidates have been overlooked in the recent focus on the precollege student. Page 24

Technology

Sample preparation for chromatography; dimethyl carbonate synthesis; enzyme mimics of iron-zeolite; catalysts for alkane activation; electron hopping; mechanism for carbon oxide reduction; olefin epoxidation by electrochemical method. Page 25



Special Report

The electronic industry's growing need for crystals has been the impetus for accelerated research efforts in hydrothermal crystallization. Page 30

Tightening Supplies Push Up Ethylene Price

Price of monomer this month is forecast to be more than 15 cents per lb, up 15% from June, as increasing demand puts squeeze on supplies

Bruce F. Greek, C&EN Houston

This month control of ethylene marketing has shifted back to producers. Once again producers are setting prices after several years of buyers dictating what they will pay for the monomer. The change stems from tightened supplies of ethylene and other large-volume olefins and from the likelihood of tight supplies continuing, at least for the near term.

The change is evidenced by the large jump in ethylene price during the third quarter. In June, nearly all ethylene sold at about 13.5 cents per lb. The price in September is forecast to be 15.5 cents per lb, an increase of almost 15%. Addi-

tional price increases are predicted for the fourth quarter.

Until recently, buyers of ethylene based what they were willing to pay for the monomer on current tabs for the various possible feedstocks for steam crackers—ethane, propane, butane, condensate from natural gas production, naphthas, and gas oils. Despite firming of world crude oil prices this year, cracker feedstock prices have risen very little during the second and third quarters, because pressure has remained on natural gas prices. Some natural gas producers have closed down wells during the summer, rather than accept current offering prices. Moreover, relatively excessive supplies of gasoline during the summer have dampened the value of naphthas and gas oils to petroleum refiners, causing the intracompany transfer prices of these materials to hold.

Ethylene demand began increasing in late 1986, with much of the demand pressure coming from producers of polyethylenes, polyvinyl chloride, and polystyrene. In first-half 1987, production of low-density polyethylene rose 6.3%, high-density polyethylene rose 8.6%, polyvinyl chloride 8.0%, and polystyrene 10.3%, according to data from the Committee on Resin Statistics of the Society of the Plastics Industry.

Producers of polypropylene also have increased their demand for propylene, a major coproduct of ethylene. This has added pressure to operate steam crackers at higher levels. It also has caused propylene prices to rise more than have ethylene prices.

Currently more than 75% of U.S. ethylene production eventually becomes components of polymers. Polyethylenes consume about 50%

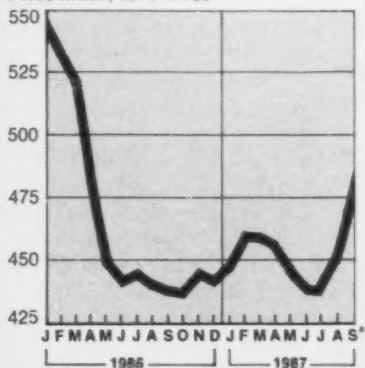
of ethylene output. Various linear olefins and alcohols and derivatives of ethylene oxide (excluding glycol in polyesters) are the larger volume uses of ethylene other than polymers.

Estimated production of ethylene during the first half of 1987 totaled 16.8 billion lb, according to the U.S. International Trade Commission. If annual production amounts to 33.7 billion lb, the industry will operate at more than 95% of average nameplate capacity, which is about 35.2 billion lb of ethylene in 1987. According to the preliminary ITC estimate, more than 32.8 billion lb of ethylene was produced in 1986, when less capacity was available.

Consumption of ethylene could exceed production. The Petrochemicals Committee of the National Petroleum Refiners Association estimates that ethylene consumption for first-half 1987 totaled 17.2 billion lb. According to the NPRA committee, ethylene consumption for 1986 totaled 32.9 billion lb, which was very close to estimated production.

Price of ethylene has turned around

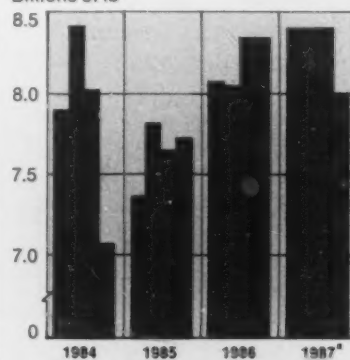
Price index, 1973 = 100



a C&EN estimate. Source: Department of Labor

Ethylene output may tail off later this year

Billions of lb



a Third and fourth quarters are C&EN estimates. Source: International Trade Commission

Production and consumption statistics aren't very reliable, so making an accurate estimate of ethylene inventory changes isn't possible. Inventories reported on surveys made by the NPRA committee for the end of 1986 and for the end of second-quarter 1987 are very nearly the same, 1.27 billion to 1.28 billion lb. (Inventories of ethylene in the 1.0 billion to 1.5 billion lb range are considered by the industry to be adequate compared with the 30 days of production inventories common to other chemicals.)

During the third quarter of 1987, industry sources indicate, producers were trying to build inventories in anticipation of shutdowns of several large steam crackers for maintenance work to begin late in September. More crackers are expected to be shut down during the first half of 1988 for similar work. Because of strong demand for ethylene by polymer producers, including a less-than-normal decline in PVC demand during the third quarter, various industry sources question the success of the inventory building efforts. Some shutdowns for maintenance in this quarter already have reduced production, but not so much as is anticipated for the fourth quarter. The price increases put through during the third quarter also provide evidence of limited success in inventory building efforts.

Three large steam crackers having a combined annual nameplate capacity of more than 4 billion lb of ethylene currently are planned to be shut down for three to six weeks

each for maintenance and debottlenecking. That downtime likely will remove 400 million lb from production during the fourth quarter. The lost production could be larger should problems be encountered during restarting. Additional production could be lost if any of the remaining operating plants develop problems, which is somewhat more likely than usual because many plants have had maintenance shutdowns deferred to take advantage of improving demand.

More maintenance shutdowns are planned for the first half of 1988. The amount of ethylene production that could be lost in 1988 is uncertain now because all the plans for shutdowns may not be carried out. The quantities that may be lost are forecast to be smaller per quarter than those expected in the fourth quarter of 1987.

Various debottlenecking efforts by producers are offsetting production lost from maintenance shutdowns. Some of those efforts won't require plant shutdown—for example, improved computer process control, which will step up efficiency. Other efforts made on units that are running may have a small effect on production. Larger debottlenecks usually are made during shutdowns, and typically in 5 to 10% of the previous nameplate capacity of the steam cracker plant.

How much debottlenecking efforts will add to capacity is difficult to estimate. Company managements often are unsure of the amount until months have passed and the debottlenecking can be assessed. Industry sources estimate that debottlenecking during the first three quarters of 1987 has added 4 to 7%, or 150 million to 250 million lb, to operable capacity.

The capacity total for the U.S. ethylene industry now ranges from 35.2 billion to 35.4 billion lb, up from about 35.1 billion lb at the beginning of 1987. Another 100 million lb, possibly as much as 200 million lb of capacity, is expected to result from work done during the maintenance shutdowns of the upcoming quarter. Consequently, when 1988 opens, capacity will have risen to more than 35.5 billion lb, the highest in several years.

Demand growth for ethylene may continue to slow for at least a year, relative to growth so far this year. Part of the slowing will stem from limitations on availability resulting from the small capacity additions, and part will result from the now nearly full use of capacity in ethylene consuming plants. Polyethylene capacity, for example, will be increased, but these increases generally haven't taken place yet. Beginning with the fourth quarter, monthly gains in production and sales of ethylene-based plastics won't be so large as those in the fourth quarter of last year. Polyethylene price increases (C&EN, Sept. 7, page 16) have resulted from tightening in the supply of polymers and from the increases in monomer prices.

Industry sources do not expect the pressure on ethylene demand and subsequent price increases to be so great as those for other olefins produced in steam crackers. Propylene specifically has had large price increases this year, with polymer grade at the beginning of September selling for 18 cents per lb, up from about 10 cents per lb at the beginning of 1987. Demand for propylene has become so strong that this month the U.S. began to import the monomer; the U.S. had been a small exporter of propylene. In addition to limitations in propylene production in steam crackers (even though operators have shifted their feedstock composition toward increased propylene production), refinery sources are limited in capacity to purify propylene relative to demand.

Butadiene prices also have risen radically because of increased demand pressure and production and imports limitations. Last October, butadiene prices dropped to 9 cents a lb; demand in making styrene-butadiene rubber was weak. Now, with demand strong and both production and imports limited, butadiene prices are nearing 30 cents per lb. Because ethylene demand is so strong and economics now favor use of lighter hydrocarbons as feedstocks for steam crackers, the likelihood of any marked increase in butadiene production near term is small. □

Ethylene use dominated by polymers, polymer materials

Billions of lb	Consumption	
	First-half 1987	% share
Low-density polyethylene	4.46	25.9%
High-density polyethylene	4.13	24.0
Ethylene oxide	2.56	14.9
Vinyl chloride	2.18	12.7
Ethylbenzene	1.23	7.1
Others	2.66	15.4
TOTAL	17.22	100.0%

Source: National Petroleum Refiners Association, Petrochemicals Committee

Chlorinated solvent use hurt by federal rules

The chlorinated solvents industry is coming under increased pressure from regulatory and environmental groups. And that pressure is causing declines in demand for the main chlorinated solvents—methylene chloride, trichloroethylene, perchloroethylene, and 1,1,1-trichloroethane.

The drop in demand doesn't mean necessarily that consumers of these products are using less, but rather that they are recycling more of the product. For instance, in the case of dry cleaning, because of new technologies, recycle rates now approach 98 to 99% for perchloroethylene, according to William Seitz, executive director, Neighborhood Cleaners Association. As a result, demand for perchloroethylene this year will be about that in 1980, he says. Seitz was speaking to a chlorinated solvents seminar, held in New York City earlier this month and sponsored by the Halogenated Solvents Industry Alliance (HSIA), a Washington, D.C.-based industry group.

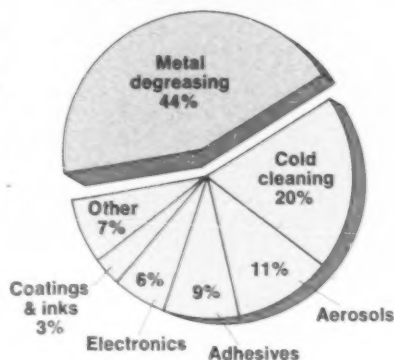
U.S. demand for virgin solvents will be about 1.5 billion lb this year, according to R. Bradley Lienhart, chairman of the board of HSIA and business manager, solvents and industrial chlorides business, Dow Chemical. However, in addition to the 1.5 billion lb marketed for first-time use, 400 million lb of solvents are recycled "internally" by the user and another 260 million lb are recycled externally by service companies.

Lienhart says recycling accounts for most of the decline in growth in the chlorinated solvents industry, but other factors have contributed. These include a switch to aqueous solvents by some end users and also the loss of markets, particularly metal cleaning uses.

To allay further regulation of chlorinated solvents, HSIA has borrowed the "product stewardship" banner from Dow Chemical, one of its leading supporters. Lienhart says that producers, distributors, and users must initiate an "enhanced product and environmental stewardship" effort, bringing a commitment to use

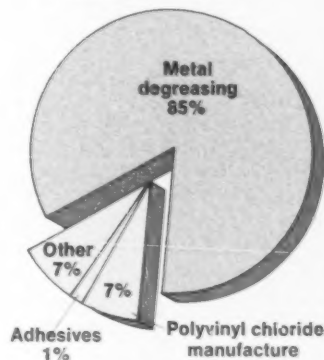
Degreasing is big market for chlorinated solvents

1,1,1-Trichloroethane



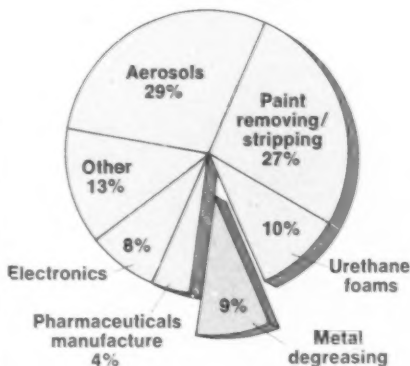
Total 1985 = 568 million lb

Trichloroethylene



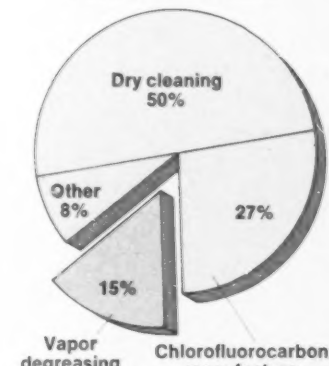
Total 1985 = 178 million lb

Methylene chloride



Total 1985 = 551 million lb

Perchloroethylene



Total 1985 = 350 million lb

Source: Halogenated Solvents Industry Alliance

the solvents more safely and efficiently, and with a greater regard for the environment.

The effort involves communication and education in terms of product safety, worker safety, and technology available, he explains. There are, for instance, 200,000 dry cleaning establishments that use a drum or more of solvent per year. Though HSIA and the manufacturers may not be able to get the message downstream enough to cover all of these outlets, distributors can. The big distributors are getting into the program, he says.

Further, according to Lienhart, manufacturers are providing more technical service to customers in terms of plant operation and worker safety. Besides the "product stewardship" benefit, this approach can

pay off in terms of increased value added for what are essentially commodity products. As with other commodities, however, the value-added approach is fraught with danger. Since the solvents are commodity products with no distinguishable differences from manufacturer to manufacturer, a user can switch to a lower-priced source after the solvent maker has provided it with technical assistance. To counter this, Lienhart says, all of the major solvent manufacturers must be involved and all must provide essentially the same service. All HSIA producer and distributor members, Lienhart adds, have their own variations of the enhanced product and environmental stewardship program.

William Storck, New York

International conference
focuses on heteronuclear clusters
Page 31

OCTOBER 5, 1987

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2

ANIMAL DRUGS

Strong growth is resuming Page 51

News of the Week

■ **Catalytic role of chlorine in depletion of stratospheric ozone over Antarctica is confirmed, according to preliminary data from Antarctica expedition.** Page 6

■ **In effort to boost role of minorities in science and engineering, National Science Foundation establishes first two centers under its new Minority Research Centers of Excellence program.** Page 7

■ **Office of Technology Assessment review supports Centers for Disease Control study that said it would not be possible to identify which Vietnam veterans were exposed to agent orange.** Page 7

■ **Conservationists urge overhaul of U.S. environmental policies and institutions to deal effectively with environmental problems.** Page 8

■ **NL Industries halts attempts to spin-off its chemical unit, more than a year after it first announced its plan to spin-off the unit.** Page 8

Cover: Veterinarian injects banamine antiarthritic agent at Schering-Plough's animal health research center, Cream Ridge, N.J.
Photo copyright John Alexanders, Black Star

Letters 4

Concentrates

Business 11

Government 19

Science/Technology 26

The Departments

New Products 73

ACS Comment 85

Meetings 87

Newsprints 108

Business

Edwin Holmer, this year's Society of Chemical Industry medalist, takes a retrospective look at the petrochemicals industry. Page 16

Government

As preshipment inspections of U.S. exports increase, chemical firms complain of delivery delays, interference with negotiated prices. Page 20

Science

Cluster chemistry opens new vistas in organometallic research, leads to commercial breakthroughs in catalysis, ceramics. Page 31

Attendees of workshop on scientific fraud and misconduct offer different professional perspectives on this complex issue. Page 44

Books

Author Maurice Goldsmith advocates need for "science critic" to help enhance understanding needed to form public policy. Page 74

ACS News

National Chemistry Day plans advance, in what promises to be most publicly visible program ever for the society. Page 80

Product Report

Growth in animal health products market resumes, in response to return to profitability of livestock industry, increased research spending, and changes in government regulatory climate. Page 51



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LETTERS

Safe hotplates

SIR: The report of the explosion during peroxide treatment of fiber samples (C&EN, Aug. 3, page 2) raises appropriate points not only about nomenclature, but also about ceramic-topped hotplates.

A few years ago, a pedologist in our earth science department borrowed the use of my perchloric fumehood to treat clay samples with perchloric acid according to a well-established procedure. The samples, in beakers, were moistened with diluted perchloric acid and heated in a sandbath on a Corning ceramic-topped hotplate. Before the work was abandoned, three hotplates had been shattered. Fortunately, no pieces flew more than a few inches, but still-live heating elements were exposed.

The point to remember seems to be that for some purposes, metal-topped hotplates are much to be preferred for safety.

G. F. Atkinson

Associate Professor of Chemistry
University of Waterloo, Ontario, Canada

Nuclear waste disposal

SIR: I am responding to a comment made by George W. Price (C&EN, July 27, page 3). According to Price, the solution to nuclear waste disposal problems is to set aside a square mile of desert, build a warehouse, and surround it with a cyclone fence posted with signs saying, "If you cross this fence you will die." I happen to live in the desert Southwest, and I like it here. One man's wasteland is another man's paradise. If Price wishes to build a nuclear waste dump, let him volunteer a square mile of midwestern lake shore (maybe somewhere in the Chicago area) and keep his hands off my desert.

Mike Hosea

Las Cruces, N.M.

Fraud and coauthorship

SIR: Inaccuracies in a recent letter by Ravi K. Agrawal (C&EN, Aug. 10, page 4) detract from his comments regarding fraud and coauthorship.

A more careful reading of the News Focus article "Misconduct in Research" by Pamela S. Zurer (C&EN, April 13, page 10) would have provided the information that when a postdoctoral research associate of Alex Nickon submitted fabricated research results for publication, he did so totally on his own. Referral to the original literature in

question confirms that Nickon is not a coauthor of the fraudulent papers themselves, nor is he cited in the subsequent refutations of these papers. The study might have provided additional perspective for Agrawal's examination of the principles, practices, and responsibilities of coauthorship in the chemical sciences.

Martin Hulce

University of Maryland Baltimore County
Catonsville

Doing business with China

SIR: It seems to me that the article on U.S.-China trade (C&EN, Aug. 10, page 6) omits an important factor that contributes to limiting the success of U.S. companies doing business with China. As someone who spent several years before retiring in seeking opportunities in China for my last employer, I had ample opportunity to observe the efforts of many companies from around the world in that country. My conclusion is that non-U.S. companies have entered that arena with a plan/strategy and a commitment to stay in there for the long haul whereas their U.S. counterparts take a more opportunistic approach.

The article correctly touches on the difficulties of dealing with the "intricate Chinese bureaucracy" and this will not change for some time. However, companies wishing to establish a position of any kind there must take into account limitations such as the bureaucracy, scarce hard currency, etc. that exist now, and establish a position for the future.

T. L. Heying

Consultant
Clearwater, Fla.

Antibacterial peptides

SIR: I write after reading the science article by Ron Dagani, "Antibacterial Peptides Isolated from Frogs" (C&EN, Aug. 17, page 27). The article is prompted by the publication by M. Zasloff [Proc. Natl. Acad. Sci., 84, 5449 (1987)] of the amino acid sequence of two 23-residue peptides isolated from the ventral skin of the toad *Xenopus laevis*, and the observation that these peptides (named magainin 1 and magainin 2) possess antimicrobial activity. The characterization and activity of these peptides have been hailed in the *New York Times* (July 31) and the *International Herald Tribune* (July 31) as a great discovery by the National Institutes of Health. Zasloff is cited in

Preshipment Inspection of U.S. Exports Irks Chemical Industry

With inspections increasing, chemical firms complain of delivery delays, higher transaction costs, interference with negotiated prices

David J. Hanson, C&EN Washington

The sweeping trade legislation now being considered by a House-Senate conference committee contains many provisions designed to protect U.S. jobs and open up markets for U.S. exports. These provisions include, in part, an extension of the government's tariff negotiating authority, certain restrictions on trade with nonmarket economies, and mandatory retaliatory actions against nations with excessive trade surpluses with the U.S., if reductions in those surpluses cannot be negotiated.

Although all these are important, another aspect of international trade has been getting considerable attention lately but is virtually untouched in the trade bill. That is the operation within the U.S. of preshipment inspection (PSI) companies, who, working under contract from foreign countries, ensure that U.S. exports to those countries meet quality, quantity, and other requirements. These companies have expanded enormously in the past few years, and, in the opinion of many exporters, have become a considerable nuisance to trade.

They became such a problem, in fact, that last September four trade associations in Florida filed a petition seeking government action against five Caribbean and Latin American nations because the preshipment inspection companies hired by these countries allegedly created a major impediment to U.S.

exports. The petition was subsequently withdrawn when the Office of the U.S. Trade Representative (USTR) launched a five-point action plan to investigate the alleged problems.

The plan includes monitoring of preshipment company activities and complaints from exporters, and initiation of discussions with a number of nations to try to determine the scope of the problem. The office also has held bilateral discussions with the nations that use preshipment inspection firms to see if the practice can be discouraged. And, as a final resort, the trade representative is looking into legislation that might ease the problem. But the first major step set out in the action plan was a fact-finding study by the International Trade Commission (ITC). That report was released in late August.

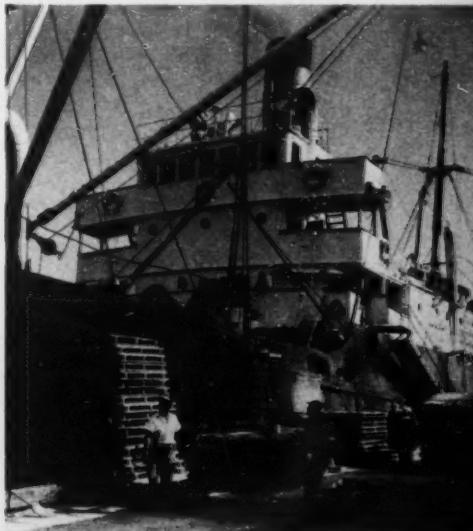
Two hearings were held by ITC—one in Florida and the second in Washington, D.C. Testimony from exporters, individuals, and the private inspection companies provided the agency with the information for its report. Particularly striking about the issue is that the chemical industry appears to have more troubles with the inspection companies than any other group. Chemical companies, appropriately, are among the severest critics of these inspection companies.

Current activities of private inspection companies have three especially bothersome results, according to exporting companies. First, the inspections delay the delivery of goods, a critical factor for pharmaceuticals that might deteriorate in quality because of the delay, and for chemical commodities that have to arrive on time to meet process requirements. Second, an inspection results in increased documentation

and transaction costs for the exporter. Third, there is widespread concern that the inspection companies arbitrarily interfere with negotiated prices.

Although the problems alleged by the exporters have mostly come about in the past three years, preshipment inspections have been conducted for many years. According to the ITC report, ever since the 1800s individual exporters and companies have used independent inspections to verify the quality and quantity of commodities moving in international trade. Companies still use it today. This provides some guarantee that the proper amounts and quality of products are maintained during the shipping process. The fees for independent inspection services are paid for by either the purchaser or supplier.

In the late 1960s, some African countries, responding to enormous debts and flight of scarce foreign capital, contracted with private com-



Preshipment inspections of exports have risen markedly in past few years

panies to help them prevent fraud in their imports and exports. Their emphasis was still on verifying the quality and quantity of shipments.

The current controversy arose when nations in the Caribbean and Latin America began hiring PSI companies to help them control capital flight by getting a handle on imports. However, a new twist was added to the traditional inspections. In addition to quality and quantity verification, the PSI firms now were also verifying the prices of shipments to ensure that the exporter was not overcharging the importing nation. It is price verification that has become one of the more contentious problems.

"Quite simply, preshipment companies can and do unjustifiably interfere with negotiated price agreements between an exporter and an importer by employing inspection standards that vary from the objective formula and statistically acceptable practices used to establish market prices," said Armin F. Vaihinger, marketing manager for the international department of the Geon Vinyl division of B. F. Goodrich to ITC in April. "The chemical and pharmaceutical industries are where there has been an intrusion from a price point of view, because the inspection companies just don't know how to get a handle on the prices," says Max Turnipseed, manager of international trade affairs for Ethyl Corp. In trying to find an acceptable market price for a commodity, "they are trying to get into something that it has taken years for people in the industry to understand," he says.

The ITC investigation determined that PSI firms use a variety of yardsticks to measure prices. These include market information from commercial sources, publications of trade associations, government reports, the manufacturer's price list, or comparable current sales invoices from other shipments. ITC concludes, however, that there appears to be no specific formula used in performing price comparisons.

For their part, the inspection companies say they are doing what their contracts call for and are providing a useful service. In the U.S. there are three preshipment inspection

U.S. chemical exports to countries using preshipment inspection have declined in past two years

\$ Thousands	1986	1985	1984	1983	1982
Angola	\$ 2,452	\$ 4,424	\$ 2,981	\$ 2,562	\$ 4,293
Bolivia	4,364	6,374	7,576	8,712	7,791
Burundi	0	37	33	1	3
Congo	610	362	90	201	578
Ecuador	125,433	119,774	105,168	80,745	117,857
Equatorial Guinea	0	0	0	3	124
Ghana	19,892	4,548	1,637	8,895	37,303
Guatemala	76,089	75,921	83,321	78,528	81,627
Guinea	358	3,304	570	734	806
Haiti	13,022	14,402	15,449	14,409	14,662
Indonesia	216,422	167,271	238,201	252,942	251,169
Ivory Coast	9,548	5,363	5,550	8,035	9,223
Jamaica	45,693	48,288	51,846	53,382	73,608
Kenya	11,827	15,862	10,310	16,832	10,115
Liberia	2,694	3,545	3,576	4,807	4,212
Madagascar	1,035	1,436	697	522	73
Mexico	1,255,669	1,408,560	1,268,664	1,104,564	1,187,955
Nigeria	42,890	54,161	44,269	52,204	52,578
Paraguay	4,520	4,507	3,310	3,277	9,430
Rwanda	18	12	115	5	27
Surinam	15,059	22,363	26,222	29,481	29,084
Tanzania	7,563	4,394	13,337	2,424	3,971
Uganda	41	121	402	68	310
Venezuela	491,428	448,596	553,527	376,524	493,204
Zaire	2,261	3,155	2,671	3,037	3,465
Zambia	731	4,141	6,122	3,061	7,210
TOTAL	\$2,349,629	\$2,418,921	\$2,445,644	\$2,103,955	\$2,400,478

Source: U.S. Department of Commerce

companies working for foreign nations. The largest by far is SGS Control Services, which is a subsidiary of Société Générale de Surveillance, headquartered in Geneva. In 1986, 23 of the 25 nations that require preshipment inspection employed SGS, according to ITC. Other PSI operations in the U.S. are performed by Intertek Services International of Fairfax, Va., which works with the British company Caleb Brett International. The third firm is the French company Bureau Veritas.

PSI companies claim that several advantages arise from the use of their services. The foremost is that, by protecting a nation from excessive capital flight, PSI promotes economic growth and new market opportunities for U.S. exporters in those developing nations. According to Franklin D. Kramer, attorney for SGS Control Services in Washington, D.C., "It is critical to recognize that the countries put these programs on a worldwide basis because of the problems they face at

home." Inspections also are supposed to streamline import and customs procedures in developing countries and encourage responsible behavior by exporters of all nations, to the advantage of U.S. companies that must comply with the Foreign Corrupt Practices Act. During the ITC investigation, SGS backed up these claims with letters from U.S. banks and investment institutions praising the PSI company's efforts to meet these goals.

Exporters, however, don't see the situation quite the same way. Ralph Chew, president of the National Federation of Export Associations, told ITC commissioners, "To a large extent, PSI activities are a phony program to pretend that the problem of capital flight is being solved. The direct and indirect costs of PSI activities are simply out of proportion to any benefit derived from them." Ida Watson, manager of foreign regulations and export services for Hercules, agrees that PSI companies are a problem. "Inspection

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- Hydrogen-storage alloys (La)
- Aluminum alloys for higher temperature service (Ce)
- Magnetostrictive devices (Tb,Dy)
- Heat-resistant MCrAlY metals (Y)
- Dispersion-strengthened nickel and titanium alloys (Y,Er)
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- Superconductor precursors (La,Y)

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companies have been known to arbitrarily reject our prices," Watson says, "even after documentation has been given to support the price. We view these PSI activities as an unfavorable restraint of trade." This was echoed by Anthony Barone of Warner-Lambert speaking on behalf of the Pharmaceutical Manufacturers Association. "Given current massive trade deficits, U.S. companies need to export. But the activities of the PSI companies are dissuading U.S. companies from selling their products abroad," he says.

Trade is being hampered, exporting companies say, because of the direct and indirect costs of inspections. Although the PSI company's fees are paid for by the importing country (between 1 and 2% of the shipment price, according to the ITC investigation) there is a cost to the exporter. Much of this comes from increased paperwork and shipping delays. "It roughly takes two weeks longer, plus or minus a day or two, for us to have papers ready for presentation of payment on a shipment that is subject to PSI as compared with one that is not subject to inspection," says Ethyl's Turnipseed. "Even when there are no questions being raised about the price, no hitches of any kind, just the sheer paperwork is a built-in delay," he says. This has been denied by the PSI companies.

During the ITC investigation, many companies reported problems in getting inspectors to the shipments when needed. Even SGS admitted that some of the delay was due to the very large increase in the number of countries using PSI firms and a lag in these companies' ability to keep up. ITC reported that the shipping process took 14 days longer, on average, for shipment to countries that require PSI than to those that do not. Of 178 chemical companies responding to an ITC survey, 35 cited costly delays as their primary concern with PSI.

Speaking for SGS, attorney Kramer says that this situation has been largely corrected. One step SGS has taken since the complaints were filed is the opening of a new center in Miami, which handles all of the SGS South American programs in the U.S. Kramer goes on to say that



Turnipseed: sheer paperwork is delay

greater internal use of computers and communications of exporters with PSI companies by electronic mail have helped speed the process. "We also have instituted an appeals process," Kramer says, "so a person with a problem can appeal directly to our president and have that problem looked at promptly."

Yet, at least for the chemical industry, the problems persist. "It's fine to say that all the problems are over, but that's just not the case," says K. James O'Connor, the legislative representative for international trade at the Chemical Manufacturers Association. "There has been some improvement in some situations only because SGS has targeted some of the more vocal critics." Turnipseed agrees. "At Ethyl, we still experience the same level of delay, whether the price is questioned or not," he says. "There is a built-in delay of at least five working days before you can get the paperwork processed." And these delays are costing exporters and manufacturers money.

The ITC report concludes that the average cost to an exporter from delays caused by PSI is about \$530 per shipment, although CMA's O'Connor estimates that the value is closer to \$750 for chemical companies. Much of this cost results from extra personnel hired to follow through with the procedure. Added to that are the extra courier

fees and telephone calls associated with PSIs and monetary losses due to delayed payments. "Your money is tied up somewhere from producing a good," O'Connor says, "and you're paying interest on that money until it's paid back. So PSI, which is delaying shipment for up to three times as long as when PSI is not required, is costing you."

Another serious concern of the chemical industry is the requirement that they give the PSI company confidential business information before the inspection company will allow payment on a shipment. ITC says that chemical exporters have complained loudly that information such as prices to individual customers, contractual arrangements, product formulas, and data on price calculation are being demanded by inspection firms. This information is often considered proprietary, especially in the competitive chemicals and pharmaceuticals markets, by companies and by the federal government. Many instances have been recorded of PSI firms telling a manufacturer the price of a competitor's product while doing a price inspection. Also, paperwork has been delivered to the wrong company, revealing competitors' prices.

SGS says that the information it requires is not confidential business information, but is information that is available to many other persons and organizations such as customs services, banks, exporters, and insurance companies. Attorney Kramer says that SGS has even revised its "request for information" form "to make it clear we are only asking for a limited amount of information so exporters do not feel they have to turn over the whole store."

There is also the problem that PSI companies offer no guarantee that they will try to maintain the confidentiality of the information they collect. ITC reports that some firms have been able to make informal arrangements for confidentiality on a case-by-case basis, but at least one case is recorded where a chemical company asked SGS to sign a secrecy agreement covering company data and SGS refused. Turnipseed says that no one is sure what the PSI companies do with the data they collect, but in SGS's case there is

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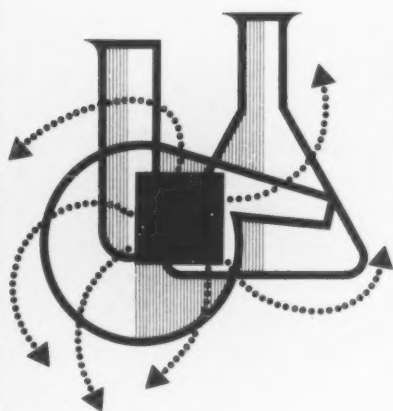
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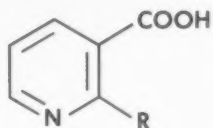
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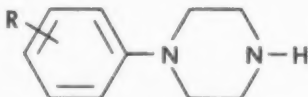
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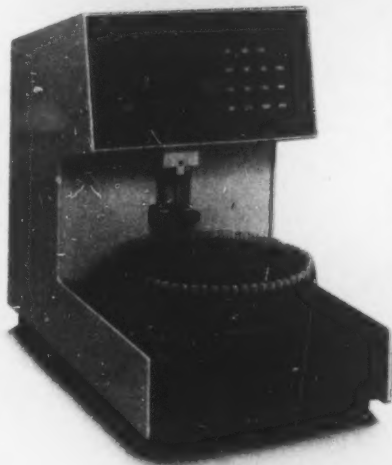
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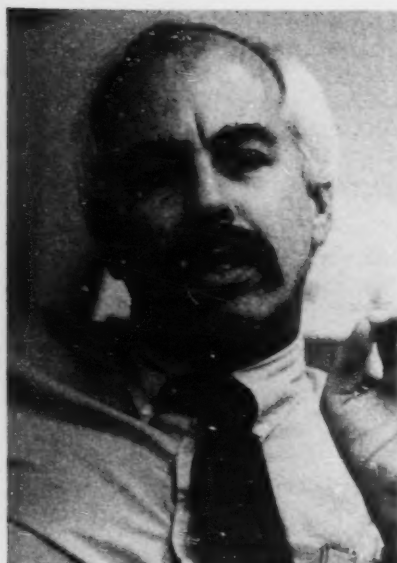
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evidence that they are sent on to the home office in Geneva. If so, there is some concern that the data could be used by Swiss-based international trading or banking firms competing against U.S. interests.

To top off all the mechanical and nuisance problems U.S. exporters are having with PSI companies, they have serious doubts that the nations hiring the companies are getting their money's worth. "Factually, there is no way to be certain," says Turnipseed. He claims that some countries are obviously not pleased with the service they are getting. Jamaica, which has had a PSI agreement for only a year, has dropped its contract with SGS. Guatemala and Ecuador are reconsidering their present contracts and may not renew them. Bolivia is also changing its PSI contract. Peru is the latest major South American country to begin a new PSI program, and its continuance will be contingent on the inspection company proving that it is saving the country at least twice the program's cost.

There is evidence in the ITC study that appears to back up the claim that countries may not be saving as much as they had hoped. All the PSI firms operating in the U.S. were found to question prices more often than product quality, ITC reports. Yet savings from price reductions amounted to only 1.2% of the total value of shipments reported inspected by the three companies. Companies answering the ITC survey reported that a total of \$1.8 million in revenues were lost because of forced price reductions in 1986. This may not be enough to recover the expenses a nation has had in hiring the PSI company in the first place. The inspection companies claim there have been significant savings resulting from deterrence of price gouging, but this cannot be documented. Industry representatives, not unexpectedly, say there has never been a problem with fraud by U.S. exporters, and there is no need for price inspections.

And price inspections aren't the only area where companies have doubts. The quality and quantity inspections are not what they should be either. "With regard to Ethyl, not once have [the inspection com-



O'Connor: PSI can be very costly

panies] inspected any of our shipments for quality," says Turnipseed. "They have never taken a sample. Not once. And only on less than 10% of shipments have they ever questioned quantity." He says that the company has laboratory analyses done on all bulk shipments, whether a PSI is going to be done or not, and PSI companies have just taken that private report and accepted it. Chemical and pharmaceutical companies question whether PSI inspectors are qualified to make quality determinations without sending samples to a lab. John Saunders, manager of international programs for the New York Chamber of Commerce & Industry, told ITC, "Many inspectors lack the product knowledge necessary to perform their tasks, and, as a result, many of the inspections are no more than cursory appraisals of highly sophisticated products."

In addition, exporters claim that the nations hiring PSI companies are violating terms of the General Agreement on Tariffs & Trade, especially Article VII on the customs valuation code, which, in part, prohibits the use of arbitrary or fictitious customs values. SGS counsel Kramer says the position of his company is that the nations employing inspection companies are not signers of the tariff agreement and are not bound to its stipulations.

Even so, PSI companies argue that

their actions are consistent with the valuation rules, maintaining that the article in question allows importing countries to compare prices for like merchandise as they are determined "in the ordinary course of trade." The chemical industry has testified otherwise. It told ITC that the PSI programs go beyond what is reasonable even if the objectives are legitimate. "PSI programs... amount to totally unreasonable and unacceptable government practices regulating—no, disrupting—international trade," Turnipseed says.

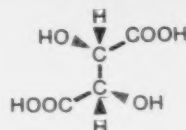
If agreements cannot be reached among the parties involved, Congressional action may result. Some European countries, where PSI problems are also on the increase, have passed laws limiting the activities of PSI companies. In the U.S., a last-minute amendment to the House trade bill by Rep. Daniel A. Mica (D-Fla.) to regulate PSI companies has been criticized by all sides and probably will be dropped when the bill is in conference committee. Donna LaTorre, acting director of the Congressional Export Task Force, says that PSIs are not a big concern at the moment, but there is a move to hold hearings on the issue in the Senate next year that could lead to new legislation.

Industry thinks there could be another way around the problem. If foreign nations feel that mandatory PSI inspections are necessary for U.S. exports, then the place to do them is in the importing country, Turnipseed says. The inspection companies could do their job at the importing end and probably save the nation money, he contends. Exporters, if there was a concern, could put up a bond to assure the shipment was proper, an action commonly done already.

The problem may not seem like a major issue in the scope of all international trade, but it is a real one. Although not a major economic burden to major companies, small exporters and manufacturers can be hurt badly. "It's a specious argument to say that PSI doesn't cost that much," says CMA's O'Connor. "If you're the product manager of a company that is being hit with price reductions and delays, it's costing you a lot."

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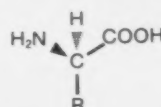


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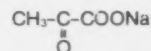
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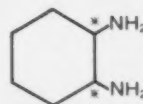
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Animal Health Products Recovering Momentum

Steven C. Stinson, C&EN New York

The U.S. market for animal health products climbed 6% in 1986 from 1985 to \$2.1 billion, according to the Animal Health Institute (AHI), which represents producers of animal health products. AHI ascribed the rise to the return to profitability of the livestock industry. Business Trend Analysts, Commack, N.Y., predicts that this trend will continue, leading to annual growth rates of 5% over the next 10 years.

During the high-inflation period from 1977 through 1980, animal health products grew 15% yearly in current dollars. From then through

1986, subsiding inflation coupled with a depressed farm economy limited annual growth to 2%.

The Commack consulting firm also cites changes in the government regulatory climate and increased research spending by industry as factors that will contribute to renewed growth. The one-time concern over use of subtherapeutic levels of antibiotics in feed has abated, leading to resumption of prosperity in that product area. Development of safer, more effective drugs is a further spur to increased dollar sales. And the weakened dollar is tending to strengthen exports as a source of sales to U.S. producers.

The relatively exposed living conditions of animals, whether outdoors or housed, the manner of feeding them, and the economics of keeping them all make the marketing climate for animal health products strikingly different from that for human drugs. Of the \$844 million spent in 1986 for veterinary drugs, for example, AHI says that \$233 million went for antimicrobials and \$611 million for such products as hormones, antiseptics, drugs against internal and external parasites, and vitamin and mineral supplements.

Animal owners purchased \$193 million worth of biologicals in 1986. This category includes vaccines, tox-

Thirty-five major firms supply U.S. animal health market

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Affiliated Laboratories
Agri-Bio Corp., subsidiary of A. H. Robins
Agripharm division of Osborne
American Cyanamid
Anchor
Beecham
Bio-Ceutic
Bristol-Myers
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Cutter division of Miles
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Rhône-Poulenc
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SDS Biotech
Salsbury
Schering Animal Health
SmithKline
Solvay Veterinary
Sterwin Laboratories
Syntex
TUCO division of Upjohn
TechAmerica
Tri-Mutual
Whitmoyer

Source: Business Trend Analysts

oids, immune sera, and blood and blood products.

The \$1.07 billion market for feed additives is the largest component of the animal health market. This is because antibacterials (\$269 million), vitamins and minerals (\$548 million), and antiparasitics are added to feed also.

Managers in the animal health industry and veterinarians classify the animals in different ways. Some speak of domestic (farm), companion (pet), and zoo (exotic species) animals. Others use the terms large (farm animals), poultry, and small (dogs, cats, and caged birds). Many think of horses as companion animals when compiling statistics.

The economics of medicating animals changes with each class. Owners of domestic animals constantly compare costs of treatment to results obtained. Business Trend Analysts does point out that use of animal health products increases livestock production 4 to 32% and saves owners \$3.00 for every \$1.00 spent.

By contrast, owners of companion animals tend to spare no expense in treating their pets. Zoo veterinarians have the same attitude toward individuals in their collections. Zoo budgets are tight, though, and veterinarians there often rely in part on donations of money and products from companies.

The distribution of animal health

care products also differs from that of human drugs. For instance, there are over-the-counter (OTC) drugs and drugs restricted to veterinary use only ("restricted drugs"). At first sight, these correspond roughly to human OTC and prescription drugs. But the Food & Drug Administration allows professional animal owners freer access to drugs as OTC products than to laypersons treating themselves. The criterion for OTC classification is whether the drug producer can write instructions that animal owners can understand and follow easily.

Thus farmers can buy oral and injectable antibiotics and antiparasitics at farm supply stores. But these same drugs are classified restricted for companion animal veterinary practice.

Farm animals also get antibiotics and antiparasitical drugs in their feed. Medicated feed is produced by about 12,000 companies in the U.S. Among the largest are Ralston-Purina, Carnation, Congra, and Land O'Lakes. These companies sell in turn to 13,000 of the 19,000 farm supply stores in this country.

The picture is complicated by the fact that many large farms have feed mills capable of blending batches of a few tons. These farmers buy antibiotics and antiparasitics directly and blend them into their feed. Many of these farmers form

farmer-dealer organizations and sell the medicated feed to their neighbors.

Likewise the U.S. poultry industry has become so concentrated that a few large producers such as Perdue buy drugs directly from pharmaceutical companies for production of medicated feed.

Dispensing of restricted veterinary drugs also differs from that for human prescription drugs. There are virtually no veterinary pharmacies where animal owners can take prescriptions to be filled. Thus veterinarians usually dispense the restricted drugs they recommend.

Many veterinarians resent the efforts of drug companies to get OTC classification for their products. These practitioners feel that these efforts undercut their roles in recommending and dispensing drugs. For their part, drug company managers feel that they must market OTC as well as restricted brands of drugs to maximize sales.

Other veterinarians have begun stocking their own inventories of OTC drugs. This move has stirred criticism from some practitioners that there is a conflict of interest in both recommending and selling OTC products. Some drug company observers feel that this criticism is justified. They point out that many veterinarians are little skilled in maintaining adequate inventories and estimating suitable markups. These observers say that veterinarians' true role is professional advice. Other drug company observers say that the move to dispense OTC drugs is a logical extension of veterinary practice, and that more veterinarians should join this obvious trend.

It is difficult to estimate the relative amounts spent on drugs for farm animals versus those for dogs, cats, and horses. AHI does not break its data out completely in this way. The American Veterinary Medical Association (AVMA) does compile information about the relative amounts spent for total veterinary care, only part of which is for drugs.

AVMA estimates that Americans spent a total of almost \$5 billion for veterinary services in 1985, the latest year for which data are available. Of this, \$3 billion was for dogs,

Product Report

\$1.1 billion for cats, \$210 million for horses, and about \$640 million for dairy and beef cattle, swine, and sheep combined. Thus dogs, cats, and horses accounted for 87% of the total.

The number of cats in the U.S. (50 million) outstripped the number of dogs (49 million) for the first time in 1985, according to the Pet Food Institute. Although the number of cats continued to grow strongly to 56.2 million in 1986, compared with 51.6 million dogs, this trend may not translate into strong growth in veterinary drug sales. This is because AVMA estimates that only half of cat owners take their pets to veterinarians, whereas three quarters of dog owners do so.

Discovering and developing new animal health products is the task of some three dozen companies in the U.S. Of these, the largest is Pfizer, whose agricultural division will sell about \$520 million worth of veterinary drugs this year. Division president Roland M. Hendrickson says that half its sales are for feed additives and half for pharmaceuticals.

Hendrickson says that Pfizer has more new veterinary drugs in development than at any time in its history. The cycle of product intro-



Ionophores are often used to treat coccidiosis in poultry

ductions that these will fuel will propel the company's growth for the next 10 years, he says. Among these, three are especially promising.

One is a quinolone antibacterial that is expected to counter the resistance of serious animal pathogens. Pfizer is developing an injectable form for cattle and swine and a water-soluble powder to be added to poultry drinking water. The second Hendrickson describes as a novel drug effective against a wide range of internal and external para-

sites. The third is an ionophore that is very promising against coccidiosis, a protozoan infestation of the intestine that causes greatest problems in poultry but occurs also in cattle, sheep, and swine. At present, the most popular drugs against coccidiosis are the ionophores monensin from Eli Lilly and salinomycin from A. H. Robins.

For the more distant future, Pfizer is working on genetic engineering projects, notably on a vaccine against heartworm in dogs, liposomes for enhanced drug delivery, and agents to improve digestibility of animal feed.

Biotechnology projects are important at many companies besides Pfizer, and they are bringing the philosophy of veterinary medicine full circle. As veterinary medicine emerged from the symptomatic treatment and quackery of the 19th century, veterinarians pinned their hopes on vaccines and antitoxins for treatment and prevention of disease. This is because they despaired of finding chemotherapeutic agents.

Then in 1932, pathologist Gerhard Domagk at Bayer's laboratory for experimental pathology and bacteriology in Wuppertal-Elberfeld, West Germany, discovered that Prontosil 4-(2,4-diaminophenylazo) benzenesulfonamide cured otherwise lethal bacterial infections in mice. Others later found that this compound was metabolized to sulfanilamide. This discovery of the first sulfa drug had greatest impact



Swine eat feed containing fenbendazole, which rids them of worms

Hoelzel-Rossel Agri-Vet Co.

Dog owners benefit from breakthrough in treating heartworm

Approval of Merck's ivermectin by the Food & Drug Administration in 1986 for heartworm in dogs was a boon to their owners.

This oral drug need be given only once a month during the mosquito season to prevent infection. Mosquitoes transmit infective larvae. Veterinarians previously advised giving oral diethylcarbamazine citrate daily without skipping a single day.

Once confined to the mid-Atlantic, South, and Gulf coasts and Mississippi River valley, this parasite has become endemic in dogs east of the Rocky Mountains in the past 20 years. Only 20% of dogs are dosed with preventive drugs, which leaves the rest as

potential reservoirs for spread of heartworm.

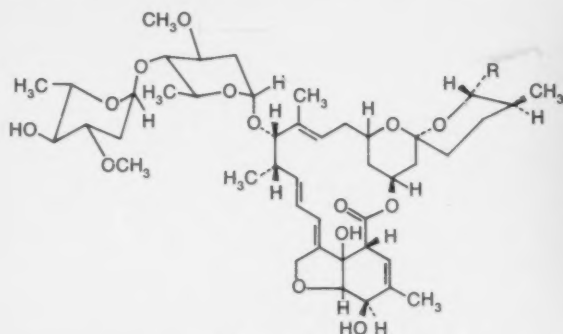
Parasitologists distinguish several life forms of heartworm (*Dirofilaria immitis*), but there are three important ones—*infectious* larvae, adult worms, and *microfilariae*. Mosquitoes deposit infective larvae on dogs' skin. The larvae penetrate through breaks and migrate through tissues and the bloodstream to the heart and pulmonary vessels, maturing to adults in 60 days.

Adults grow to 9 to 14 inches in length, clog the heart and its blood vessels, and can cause congestive heart failure in dogs. Adult worms reproduce sexually to spawn microfilariae, which circulate in the blood. When

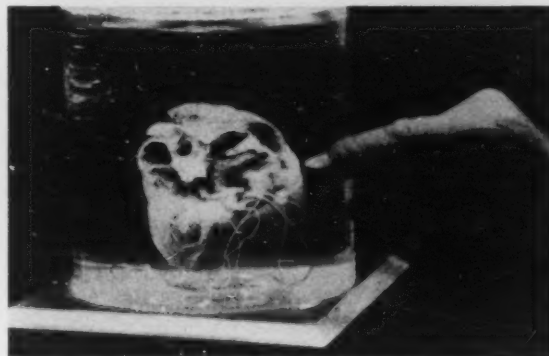
they bite infected dogs, mosquitoes ingest microfilariae, which evolve into infective larvae in the flies' kidney tissue.

Ivermectin kills infective larvae but not adult worms or microfilariae. Because infective larvae take 60 days to mature to adulthood, the next dose can be given in 30 days to kill any that have entered between doses.

Veterinarians can begin treatment of infected dogs with thiacetarsamide to kill adult worms, followed by dithiazanine to kill microfilariae. They can start ivermectin therapy at once in uninfected dogs and in others after ridding them of adult worms and microfilariae. Puppies may be treated with ivermectin at six weeks old.



Ivermectin contains more than 80% of 22, 23-dihydroavermectin B_{1a} (R = *sec*-butyl) and less than 20% of 22, 23-dihydroavermectin B_{1b} (R = *isopropyl*)



Adult heartworms live in canine heart and pulmonary arteries, reducing or blocking blood flow

on human medicine, but the philosophical implications were not lost on veterinarians. They could develop chemotherapeutic agents to supplement their biological ones.

Now, 50 years later, the rapidly developing techniques of biotechnology are being recruited by veterinarians to invent vaccines and antibodies against disease organisms. And whereas biologicals of the past were directed against bacteria and viruses, the newest work also focuses on more advanced parasitic organisms.

Pfizer's discovery of new agents occurs at the firm's research center in Groton, Conn., with developmental testing at the company's farm near Terre Haute, Ind. The veterinary research group at Groton is separate from the human medicinal units there, although they share sup-

port services. Hendrickson estimates that bringing new agents from discovery to FDA approval costs \$50 million each. This amount includes money spent on compounds that must later be abandoned.

Yet he points out that the animal health market is only one tenth the dollar value of the human one. A product that eventually reaches \$30 million in yearly sales is a big success for a veterinary drug, though puny for a human one. Thus Pfizer must develop worldwide marketing to support its ambitious research program.

One factor Hendrickson cites as increasing costs of biotechnological products is efforts to counter objections of outside critics. Though loyal to Pfizer, Hendrickson praises American Cyanamid's work on bovine somatotropin to raise milk produc-

tion. Critics question the value of adding to dairy products already in oversupply. But as Hendrickson puts it, "It's ridiculous to talk of ignoring anything that improves efficiency."

Veterinary medicinal research is more narrowly focused at Schering Animal Health, a division of Schering-Plough Corp. Division president Karl Meister says he concentrates on unique, patented, potentially high-volume agents for both food and companion animals that can be marketed on a worldwide basis.

"You must keep in mind that animal health is not a growth market," he says. "So to be a superior competitor, you must do your own research for unique patented products, and develop a critical mass." Schering Animal Health works on veterinary drugs and biologicals but

INTERMEDIATES FOR PHARMACEUTICALS

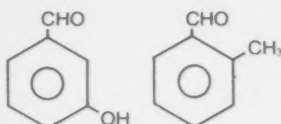
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Guanine
Deoxy-D-ribose

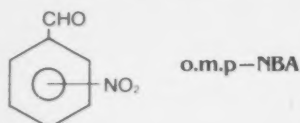
=D-AMINO ACIDS etc.=

D-Alanine
D-Glutamine
D-Tartaric acid

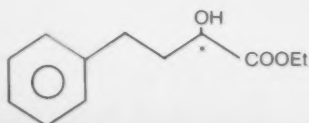
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Product Report

avoids generic compounds and feed additives. The division pursues products that can be approved in both restricted and OTC forms as part of their search for that marketing critical mass.

Some of the division's new products grow out of human medicinal chemistry at Schering's central research facilities. The division licenses such new nonhuman drugs as antihelmintics and coccidiostats from other companies. Veterinary pharmaceuticals are tested in development at the company's farm in Cream Ridge, N.J., and biologicals at its farm in Elkhorn, Neb.

Among biologicals, Schering Animal Health is very active in vaccines. Meister is particularly proud of a recent one for Potomac horse fever, a bacterial disease that kills up to 50% of its victims. The division is also seeking vaccines against equine rhinopneumonitis and influenza, heartworm, and coccidiosis. Schering Animal Health has done its own biotechnological work toward some of these products to date but is also seeking agreements with smaller biotechnology firms.

The research philosophy at Merck's MSD Agvet division starts as far back as how farmers can produce more food with fewer, more efficient animals, says William H. D. Leaning, executive director of technical services, which follows per-

formance of agents after approval and feeds back suggestions for new dosage forms, uses, or product types.

So far this has led the division into what Leaning calls applied parasitology. For example, some cattlemen minimize the importance of parasite control, even though parasites impair weight gain in young animals. The rationale is that parasite control is costly, animals usually overcome infestations themselves, and there is a compensatory weight gain later.

But MSD Agvet has done work to show that this later weight gain is mostly fat. Moreover, parasites generally slow the growth of medium-to fast-growing muscle tissues, which turn out to be the more prized and expensive cuts of meat. So divisional representatives try to persuade farmers that parasite control ultimately repays them with more efficient meat production.

In addition, heifers reach breeding weight sooner with parasite control. This results in a longer, more productive breeding life. And dairy farmers can increase milk production, allowing them to achieve quotas with fewer cows.

The concentration on applied parasitology has led MSD Agvet to depend on a few products in comparison with other firms, but two of these have been blockbusters. First, Merck developed the antihelmintic

Growth resumes for animal health care products

Type	Sales, \$ millions					
	1986	1985	1984	1983	1982	1981
Pharmaceuticals	\$ 844.0	\$ 789.6	\$ 764.0	\$ 759.1	\$ 684.0	\$ 597.7
Antimicrobials	232.9	220.9	214.7	214.8	204.8	197.2
Other	611.1	568.7	549.3	544.3	479.2	400.5
Biologicals	192.9	192.0	167.6	171.5	148.7	152.6
Large, food-producing animals	69.3	73.1	72.8	76.6	70.4	69.4
Poultry	40.3	37.4	33.5	33.3	23.0	23.6
Small animals	55.4	55.1	34.4	37.4	47.7	59.6
Rabies	10.2	9.8	10.9	9.5	a	a
Equine	17.7	16.6	16.0	14.7	12.9	a
Food additives	1066.8	999.8	1046.9	1097.9	1081.1	1078.3
Antibacterial	269.1	270.6	283.1	268.6	248.2	239.5
Nutritional	547.7	498.4	540.0	597.7	613.9	632.1
Other	250.0	230.6	223.8	231.6	219.0	206.7
TOTAL	\$2103.7	\$1981.2	\$1978.5	\$2028.5	\$1913.8	\$1828.6

a Included in figure for small animals, then called companion animals. Source: Animal Health Institute

Product Report

thiabendazole 25 years ago, which revolutionized treatment then and still sells well today. The most recent agent is ivermectin, which is effective against a wide spectrum of both internal and external parasites. The company also developed clorsulon against liver flukes and amprolium against coccidiosis.

Ivermectin is effective for long periods at vanishingly small oral or injected doses against not only a variety of tissue and gastrointestinal nematodes (round worm-types), but also such external parasitological and disease-carrying insects and arachnids as fly larvae, lice, mites, and ticks. The dose in cattle and horses is about 200 µg per kg of body weight, and that for heartworm in dogs is 6 µg per kg. As with thiabendazole earlier, MSD Agvet is pursuing approvals in most countries of the world for various dose forms, species in which to be used, and parasites to be controlled.

Ivermectin acts in parasites by

stimulating release of the neurotransmitter γ -aminobutyric acid (GABA) from nerve cells. This overloads the nervous system, causing paralysis and death. Mammals have GABA-mediated nerve transmission only in the central nervous system, and ivermectin does not cross the blood-brain barrier.

In other product areas, MSD Agvet tried to get into vaccines several years ago. But Leaning explains that vaccines themselves cannot be patented, and other, small producers were duplicating these products. These others could market their vaccines without FDA approval as long as they did not deal out of their own states. But microorganisms that produce vaccines can be patented. So the division's future plans include inventions of new vaccines by genetic engineering for a return to the market.

And the company's overall philosophy of improving efficiency of food production is leading it into

such areas as partitioning agents. These are synthetic amphetamine-like drugs that accelerate fat metabolism and slow turnover of muscle fiber. Such agents might increase efficiency of meat production in cattle and poultry.

The research effort at Hoechst-Roussel Agri-Vet Co. concentrates on food-producing animals. Research on new compounds is conducted by Hoechst in Frankfurt and by Roussel-Uclaf near Paris. Recently developed products include fenbendazole, which group product manager Terry Sheehan cites as an improvement in effectiveness over thiabendazole as an anthelmintic. The company also received FDA approval for halofuginone for coccidiosis in 1985. Sheehan says this drug is more potent and less costly to use than ionophores now on the market. And coccidia do not develop resistance against it as they have against other nonionophore agents.

Approval was given this year for trenbolone acetate, an anabolic steroid that improves feed use efficiency in cattle and increases the ratio of muscle to fat. For the future, the company is seeking approval for altrenogest, which suppresses heat in mares and sows. When the drug is withdrawn, animals come quickly into heat so that stockmen can plan breeding times.

Pig farmers can use it to develop herds whose ages are about the same. Horse owners can use it to breed mares at optimum times. Racing rules state that a horse becomes officially one year old on Jan. 1 of the year after it is born. Thus a horse born in December 1986 must already race as a two-year-old after Jan. 1, 1988.

For the veterinary pharmaceutical industry as a whole, Rainer K. Muser sees several problem areas that still need solutions. Muser, who is director of R&D at Hoechst-Roussel Agri-Vet Co., sees liver flukes as a continuing scourge. Though drugs are available to kill them, these agents are often effective against only one of the life forms. Existing drugs kill adults in animals' bile ducts. Drugs under development kill larval forms. Muser sees a vaccine as a possible, ultimate treatment.

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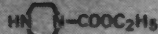
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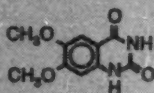
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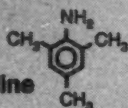
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- dyestuffs
- flavors
- fragrances
- photochemicals



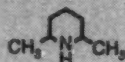
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6,7-Dimethoxyquinazoline-2,4-dione



2,4,6-Trimethylaniline Mesidine

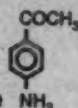
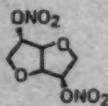


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Product Report

Vitamin E: How much is enough?

Veterinary physician Emil P. Dolensek is fond of pointing out that studies in zoos can be more revealing than those with laboratory animals. This is because zoo populations contain many species, are genetically diverse within species, and range from newborn to aged animals.

Dolensek, who heads the Animal Health Center at the New York Zoological Society (the Bronx Zoo), recently used the worldwide resources of the society to detect hitherto unsuspected pathologies of vitamin E deficiency. His findings may affect how stockmen manage farm animals.

The trail began in 1983, when Dolensek noted that five Mongolian wild horses at the zoo that lacked coordination in their hind quarters had been destroyed in the previous five years because of their condition, and one afflicted animal had died foaling. Pathologists found areas of destruction of myelin sheaths and nerve cells in the animals' spinal cords at the lower cervical and upper thoracic vertebrae.

Blood chemistries and urinalyses were normal except for abnormally low serum levels of vitamin E. All animals had been fed hay, green grass in summer, and commercial horse pellets supplemented with vitamin E.

One problem was that the optimum levels of vitamin E in exotic species was unknown. Dolensek turned to Wildlife Conservation International, a research branch of the society with scientists in 30 countries. These sent him blood samples of elephants, hippos, black rhinos, and dugongs in the wild, which were compared with samples from the same species at the zoo. Vitamin E levels in captive ani-

mals were found to be much lower than those in the wild.

Dolensek's work was hampered at first by lack of money. But Perkin-Elmer Corp. donated a liquid chromatograph for high-volume determinations of vitamin E. Technicon gave an Autoanalyzer for analyses of cholesterol and lipids, which are related to vitamin E. And Hoffmann-La Roche, a vitamin E producer, granted money to pay the salary of a nutritionist from Cornell University to work at the zoo.

In further search of pathology from vitamin E deficiency, Dolensek correlated the medical and maintenance records of animals that had died unexpectedly over the previous 10 years with the "library" of tissues preserved from them. At the zoo, all animals that die of any cause are examined post-mortem and tissue samples preserved.

He zeroed in on about 100 animals of the deer family, eight baboons, and about 100 embryos and chicks of six bird species that had failed to hatch or died within days of hatching. The hearts of all of these showed destruction of muscle and replacement by fat or fibrous tissue. In animals whose serum vitamin E levels were determined at the time, these were abnormally low. The feed of all of them and the chicks' and embryos' hens had been supplemented with vitamin E.

Dolensek concluded that levels of vitamin E supplementation were too low. Curators increased the vitamin E content of animal feeds sharply. Heart disease in mammals and birds has not been seen at the zoo since 1983.

Dolensek notes that vitamin E is also important in reproduction. This fact may affect owner practices in feeding farm animals as well.

Again, drugs are available to prevent coccidiosis but must be given constantly in poultry feed, which is expensive. Again, the solution may be a vaccine.

There is also a need for antibiotics against bacterial diseases that will treat them economically. With the withdrawal of FDA approval of chloramphenicol for use in food animals, Muser says that there is a lack of a good antibiotic for such

gram-negative bacteria as salmonella.

A common problem Muser cites in the cattle industry is bovine pneumonic pasteurellosis. Because this can strike all and especially young cattle during shipping to market, it is called shipping fever. The disease, which takes many forms, is a bacterial pneumonia caused by *Pasteurella*, combined with and brought on by stress, exposure, poor

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Product Report

How drugs get their generic names

Carbadox. Fenbendazole. Ivermectin. Hundreds of new veterinary and human drug candidates get generic names every year. Whatever brand names their sellers eventually give these compounds, the Food & Drug Administration and scientists publishing in journals will use their generic names. And when they go off patent, generic drug companies will probably use their generic names to market them.

American generic names are the etymological brainstormers of the U.S. Adopted Names (USAN) Council, founded privately in 1962 by the American Medical Association, American Pharmaceutical Association (APhA), and U.S. Pharmacopeial Convention to bring order and simplicity to drug names.

The USAN Council has offices at AMA headquarters in Chicago, where Donald O. Schiffman is secretary. Five council members—chemists, pharmacologists, and physicians—who are not paid for their work, are scattered around the country and hammer out new generic names by mail. AMA, APhA, and USP Convention trustees approve a new council yearly. Members may succeed themselves for a maximum of 10 years.

The naming process begins when a drug company asks the USAN Council to name a new compound. The council never refuses a request, Schiffman says, but usually expects the company to go as far as human or target animal testing before asking. Until 1985, naming was free. But staff support and computer search time became too burdensome to AMA, and the council started charging \$1000 for new names and \$500 for salts or esters of compounds already named.

Over the years, the council has established such stems as -cillin for peni-

cillins, -oxacin for quinolones, and cef- for cephalosporins. This last one has become "a bit of a disaster," Schiffman says. Cef- has the advantage of putting all cephalosporins together in alphabetical listings but makes the growing number of names look alike. Sometimes the council has to live with mistakes.

In the beginning, names came from salient parts of molecular structures. Recently, councilors have favored names that reflect pharmacological action, and they usually name antibiotics from the microorganisms that produce them. They avoid th, which is unpronounceable in some languages, and initial h, which is silent in others. Lack of a y in many alphabets leads to replacement by i.

The council seeks agreement on new names with the drug firms that ask for them, with FDA, and with the International Nonproprietary Names (INN) Committee of the World Health Organization. Schiffman is a member of the INN Committee, which represents nomenclature authorities of individual countries. Trial names are published in the Pharmaceutical Manufacturers Association Bulletin for criticism by its member firms.

Intense drug research in other countries often leads to compounds' getting their first generic names from the INN Committee. In these cases, the USAN Council tries to adopt the INN Committee name, unless insurmountable problems compel the council to create its own.

The council publishes final new names monthly in the *Journal of Clinical Pharmacology & Therapeutics*. The USP Convention publishes an annual dictionary of generic drug names, together with an appendix giving INN names that are different.

nutrition, and viral infection in transit. The present treatment is routine injection of all cattle with penicillin on arrival. There are yet no reliable vaccines against Pasteurella.

There is also no reliable cure for anaplasmosis, a rickettsial blood infection of cattle, Muser says. And atrophic rhinitis is a problem in

swine. The latter is an infection of the turbinate bones, a maze of thin plates in the snout, often caused by Pasteurella or Klebsiella. In severe cases the snout is severely deformed, breathing is inhibited, and animals become susceptible to other diseases. There is still no reliable vaccine for this, Muser says, and the present treatment with daily sulfonamides

Lasix commonly used in race horses

Attendees at race tracks in several states may see postings that one or more horses in a race have been given Lasix, an oral diuretic for treatment of high blood pressure in humans.

But most veterinarians believe that injectable Lasix, which is marketed by Hoechst-Roussel Agri-Vet Co., Somerville, N.J., also prevents exercise-induced pulmonary hemorrhage (EIPH). And many veterinarians and trainers believe that regardless of effect on EIPH, Lasix somehow improves racing performance.

Writers have noted for at least 300 years that a few horses finish a race with blood flowing from their nostrils. Racing records of the past 75 years show that up to 6% show this phenomenon, with the average at about 1%.

By the mid-1970s many veterinarians were critical of the practice of administering Lasix to up to 50% of horses at some tracks. These horses' veterinarians and trainers claimed that the horses bled internally, even if blood didn't reach their nostrils.

Then in 1978, veterinary medical professor John R. Pascoe of the University of California, Davis, used the then-new flexible fiber optic endoscope to screen a total of 235 horses within two hours of their racing at one track. Of these, 103 (43.8%) had blood in their tracheas, and two of the 103 later bled from the nostrils.

The cause of EIPH is still unknown. Some veterinarians suggest that tremendous increases in breathing during racing increase pulmonary blood pressures, leading to rupture of small blood vessels in air sacs. Others implicate some form of small-airway disease. With the cause unknown, use of

Lasix, steroids, and other drugs that have been tried has been empirical rather than scientific.

Both sexes and all breeds are equally afflicted. EIPH seems more prevalent in horses older than five years than in those younger, and in those that run more than eight furlongs than in those that run fewer. Of horses with a history of EIPH, about 30% will not show it after any one race.

Veterinary medical professors Lawrence R. Soma and Corinne R. Sweeney of the University of Pennsylvania have studied Lasix and EIPH. Horses that suffered EIPH in one race were divided into Lasix-treated and -untreated groups and examined after second races of equal lengths and conditions within 30 days of the first.

Among 85 such horses, a larger percentage of the untreated ones developed EIPH after their second races than Lasix-treated ones. But effects of racing and betting regulations and of trainers' own decisions whether to participate skewed the numbers in each group, and statistical analysis showed no meaningful difference.

Soma also has studied effects of Lasix on racing times in seconds per km of a total of 128 horses. Horses ran five races on various days without Lasix followed by five races with it. Soma divided them into groups according to whether or when they bled from the nostrils or into the trachea only. He compared these groups with one another and with a group of randomly chosen horses without Lasix. He also compared those that were worth more than \$10,000 (better historical performers) with those worth less. Again, there was no meaningful difference.

or tetracyclines in the feed is expensive and not always effective.

Animal populations in zoos pose their own special problems, according to Lyndsay G. Phillips Jr., associate veterinarian at the National Zoological Park in Washington, D.C. For one thing, there are almost no drugs approved for animals there. It is too costly for companies to do all the testing that would be required for FDA approval species by

species. So zoo veterinarians are left to extrapolate from treatment of domestic and companion animals of similar species.

Some antibiotics do not act the same in the "big cats" as they do in house cats, for example. Tigers do not absorb oral tetracyclines as well as house cats. Although half-lives of tetracyclines are the same in both animals, blood levels never reach therapeutic concentrations in tigers.

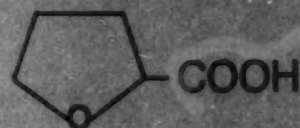
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New drug, altrenogest, would allow mares to be bred at optimum times

And reptiles are even more susceptible than humans and other mammals to the kidney-damaging side effects of aminoglycosides. At the National Zoo, veterinarians have worked out a regimen of giving gen-

tamicin to reptiles at 72-hour intervals.

On a positive note, there do not seem to be as many antibiotic-resistant strains of bacteria in zoos, Phillips says. They find that most

cases of bacterial infection are susceptible to the six to 10 antibiotics they routinely screen for. Antibiotics most used are ampicillin, carbenicillin, erythromycin, oxytetracycline, gentamicin, kanamycin, and some cephalosporins. There is a preference for long-acting penicillins to avoid the stress of dosing an animal more than once daily.

Another challenge in zoo practice is anesthesia. Animals respond differently, depending on species, sex, size, health status, and age, Phillips says. But the staff has gained a lot of experience with anesthetic doses. Recovery is also variable. Some animals awaken delirious.

"You can watch four hours of surgery destroyed in a few minutes," Phillips says. "We're very protective of the animals. We keep them in the dark away from stimuli so they just sleep it off. We keep them in crates or stalls, and we watch them to see that they don't get a head or a foot caught." □

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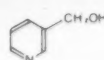
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3-pyridine methanol



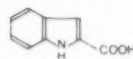
4-pyridine methanol



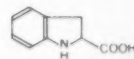
Octahydro indole



Indole-2-carboxylic acid



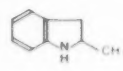
Indoline-2-carboxylic acid



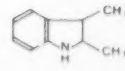
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2-Methyl indoline



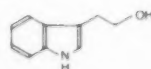
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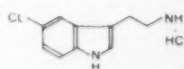
Tryptamine



Tryptohol



5-Chlorotryptamine · HCL



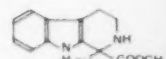
Indole-3-butyric acid



Serotonin · HCL



1-Methyl-1-methoxycarbonyl-tetrahydro-β-carboline



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Principles challenged by advances
in science and technology

Page 7

News of the Week

■ **Nobel Prize in Chemistry shared by two Americans and Frenchman; winners in medicine and physics also are announced.** Page 4

■ **State of global competitiveness of U.S. industry is key topic of discussion—and worry—of chemical executives gathered at Chemical Manufacturers Association's fall meeting.** Page 6

■ **OSHA data on occupational illnesses and injuries are inadequate, providing too little information to maintain prevention program, says NRC panel report.** Page 6

Cover: U.S. Constitution, Bill of Rights, and Declaration of Independence on permanent display in rotunda of National Archives building, Washington, D.C. Photo by Stephen R. Brown, courtesy of National Archives

Letters 2

Concentrates

Business 13

Government 23

Science/Technology 29

The Departments

ACS News 37

Meetings 40

Newsclips 56

Business

Canadian Chemical Producers' Association president talks about U.S.-Canada free trade pact and explains Canadian chemical industry's strong support for it. Page 15

Polyurethane World Congress marks 50th anniversary of polyurethane patent, looks at future of polyurethane business. Page 20

Government

Legislation being considered by Congress deals with ocean disposal of plastics, fuels for methanol-based vehicles, air emissions of toxic chemicals, and other issues. Page 26

Preventing diversion of precursor chemicals to illegal drug manufacture by closer monitoring is goal of Administration bill. Page 28

Science

Small synthetic molecules that mimic enzymes show promise as serine transacylases, in chiral recognition, and in oxidation-reduction reactions, among others. Page 30

More efficient biomimetic cyclization of polyenes is accomplished by use of cation stabilizer in research at Stanford University. Page 34

Technology

New approaches to solving problems in separation technology that focus on generic separation research are urged by NRC committee. Page 36

News Focus

Office of Technology Assessment examines dramatic impact of advances in science and technology on constitutional principles and takes a long-range look at current and possible future advances. Page 7



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LETTERS

Air pollution reports

SIR: Harry Walker (C&EN, Aug. 24, page 5) remarked about one problem caused by unquestioning acceptance of Environmental Protection Agency theories. Another problem is that very little criticism of their clean air policies is ever seen in the mass media, or even in C&EN. Local government officials in and near Denver often claim a crisis in air quality, referring to EPA reports. But the details, when published by local media, don't seem to justify the crisis atmosphere. For instance, the majority of air quality violations were reported from one monitoring station in a congested area of downtown Denver; monitors in near suburban areas often found no violations in a year or more. Appearances of a brown cloud over Denver are often blamed on motor vehicles, but the brown cloud was remarked on in 1874.

Sensational, exaggerated air pollution reports confuse us about what actually needs to be done. They also cause economic harm. Proposals to curtail freedom of travel are made by people who sound perfectly serious. Implementing such proposals would do enormous damage to the economy, and potential investors in Denver area businesses know it. And a casual reader about Colorado could easily believe that several large counties are covered by smog all winter (that is not the case).

C&EN would be a perfect forum for some criticism of the hysteria generated in the struggle to avoid EPA sanctions. I don't think we will ever see such criticism in a local publication.

Robert L. Montgomery
Littleton, Colo.

Abuse and misuse of statistics

SIR: The regrettable problem of fraud and other misconduct in science was addressed recently by Henry H. Bauer (C&EN, July 13, page 34) and by others previously. In a letter, "Scientific malpractice in epidemiology" (C&EN, April 9, 1984, page 76), pertaining particularly to the extrapolation fallacy, I referred to problems of scientific competence (or incompetence), deception, and fraud. See also, "Low-level radiation effects: Extrapolation as 'science'" (C&EN, Jan. 16, 1984, page 75). The Environmental Protection Agency, as was noted, found extrapolation to be "good science."

A letter of Sheldon Meyers, director, Office of Radiation Programs, EPA, June 3, 1987, pertaining to health effects of environmental radon, reiterates adher-

ence to extrapolation as scientifically valid. He states: "[EPA] uses epidemiological studies of underground uranium miners to estimate health effects from low levels of radon exposure. Health effects observed from the levels of radon exposures in these studies are used to estimate health effects from low levels of radon exposure. Health effects observed from the levels of radon exposures in these studies are used to estimate health effects at lower exposures using a linear/no-threshold mathematical model which assumes that cancer incidence is proportional to radiation exposure." The statement is in response to my inquiry about allegations that low levels of radon, such as are naturally emitted geologically, are hazardous to health. Meyers' comments appear to ignore effects of mine dusts and other gases, and appear to attribute all health effects, observed in miners, to radon, rather than to any other environmental variables. Further, epidemiologic findings for uranium miners can hardly be applied judgmentally to persons living in homes in which low levels of radon occur from natural geological seepage. They also ignore documented observations such as are discussed in C&EN, Nov. 3, 1986, page 2, and in C&EN, May 25, page 3.

Further information on health effects of low-level radon was provided by Bernard L. Cohen in an abstract, "Lung cancer induction by environmental radon and its potential for demonstrating hormesis," in "Program and Abstracts," Conference on Radiation Hormesis, Oakland, Calif., Aug. 14-16, 1985 (sponsored by the Northern California sections of the Health Physics Society, the American Nuclear Society, and the Department of Energy, among other groups). Cohen reports: "All studies to date indicate a strong negative correla-

Corrections

- Sept. 14, page 4: Pact on nitrogen oxides control will become a protocol to the Convention on Long-Range Transboundary Air Pollution.

- Sept. 21, page 70: In the box listing 1988 members of the ACS Council's Committee on Committees, Frederick E. Bailey was inadvertently omitted as a continuing member.

- Sept. 28, page 4: Capacity of Rhône-Poulenc's synthetic sodium carbonate operations in France is 580,000 metric tons a year, not 580.

tion between female lung cancer rates and radon exposure. Cumberland County, Pennsylvania, was found to have nine times the average radon exposure, but it has well below average lung cancer rates. A similar situation is reported in a large area in Finland, and a comparison between two well-matched areas of China gives even stronger evidence. All large areas known to have high radon exposures have below average lung cancer rates (e.g., eastern Pennsylvania, eastern North Dakota, Sweden, Finland) and in all high lung cancer rate areas where radon levels have been studied, they have been found to be below average (e.g., England, San Francisco area, New York City area)." Cohen discusses this topic further in "Tests of the linear, no-threshold dose-response relationship for high-LET radiation," *Health Phys.*, 52, 629 (1987).

Clearly, abuses and misuses of statistics occur in some epidemiological studies involving low-level radon exposure. However, warnings of such abuses have been and are being ignored by some individuals, and by some agencies such as EPA. The question of misuse of public funds, such as for "protection" against natural low-level radon, is in great need of examination.

Richard J. Hickey
Ecological Statistical Group
Department of Statistics (retired)
Wharton School
University of Pennsylvania, Philadelphia

Classifying biochemistry

SIR: A disturbing aspect of the National Science Foundation report "Profiles—Chemistry: Human Resources & Funding" (C&EN, Sept. 7, page 23) is that, for purposes of data collecting and reporting, NSF does not consider biochemistry to be a chemical science. Most would consider the five overarching divisions of chemistry to be analytical, inorganic, organic, physical, and biochemistry. However, NSF reports data for the first four only and separate data for nuclear, pharmaceutical, polymer, theoretical, general and "other" chemistry, but completely ignores biochemistry. ACS, in keeping with its newly adopted mission statement, should work to change this thinking.

Because it is a bridging discipline, biochemistry could also be considered to be a life science, and NSF may prefer to classify it that way for internal bureaucratic reasons; but to omit from the statistical analysis of employment and op-

portunities in chemistry the subdiscipline that is a major producer of Ph.D. chemists and offers many employment opportunities is most disturbing. That some educating needs to be done is suggested.

James N. BeMiller
Director, Whistler Center for
Carbohydrate Research, Purdue University

New use for tacrine

SIR: Like many others who have relatives affected by Alzheimer's disease, I was delighted to read (C&EN, Aug. 17, page 4) of the \$5 million project for clinical trials of THA. May I correct one error in this report—that the drug has been known since 1908? That was the date of Borsche's synthesis of the parent, 1,2,3,4-tetrahydroacridine of which THA is the 9-amino derivative. Rather, tacrine (to use the international generic name) was first prepared during World War II in work carried out for the Australian Army which delayed publication for three years [Albert, A., Gledhill, W., *J. Soc. Chem. Indust., London*, 64, 169 (1945)].

Its ability to stimulate the central nervous system benignly (an analeptic action) [Shaw, F., Bentley, G., *Med. J. Austral.*, ii, 868 (1949)] led to its use for promoting mental alertness in patients undergoing morphine therapy for terminal cancer [Stone, J., Moon, J., Shaw, F., *Brit. Med. J.*, i, 471 (1961)]. May its newfound use bring benefit to a new category of sufferers.

Adrien Albert
Emeritus Professor
Australian National University, Canberra

Strong commitment to safety

SIR: A government concentrate (C&EN, Aug. 3, page 17) incorrectly states that the Occupational Safety & Health Administration "has begun a comprehensive review of injury and illness record-keeping practices at all facilities operated under the names of E. I. du Pont de Nemours & Co., Du Pont, and Remington Arms Co."

The comprehensive review, in fact, was started by the companies on their own prior to reaching a negotiated settlement with OSHA on various record-keeping cases.

Over the years, Du Pont has demonstrated a strong commitment to safety and health and in this case was making every effort to comply with federal record-keeping requirements. To suggest

that OSHA has initiated a corporate-wide review unfairly characterizes the companies' efforts to identify and correct any record-keeping problems that may exist in their facilities.

OSHA's policy is to encourage every employer to do just that.

John A. Pendergrass
Assistant Secretary of Labor
Occupational Safety &
Health Administration

Up to industry standard

SIR: In the article about drugs in the chemical workplace (C&EN, Aug. 3, page 7), there is an omission that needs correction. In the chart (page 9) that lists chemical producers and their drug-screening programs, Hoechst Celanese is listed correctly as having pre-employment screening, and testing for cause.

However, Hoechst Celanese also requires urine tests confirmed with gas chromatography/mass spectrometry, and the company also provides an employee-assistance program.

We know our company's policies are up to industry standard, and we want your readers to be aware of it as well.

John D. Dougherty
Corporate Medical Director
Hoechst Celanese
Somerville, N.J.

Correct figures

SIR: I am writing to correct an error contained in a special report entitled, "Facts & Figures for Chemical R&D" (C&EN, July 27, page 32). The table on page 61 of this report, which was compiled on the basis of data provided by the National Science Foundation, listed total support of chemical research at UT, Austin, at \$4.588 million for fiscal year 1985. This reported level of funding causes the ranking of our department to drop to 27th from its position of seventh in the previous fiscal year.

Subsequent investigation into this dramatic change in research funding and ranking, as reflected in the compilation, has revealed that a mistake was made in reporting our local data. The correct figures for UT, Austin, for the fiscal year should be \$7.908 million in total funding with \$4.741 million (60%) of that being from federal sources. Consequently, our department should have been ranked sixth in the report.

John C. Gilbert
Chairman, Department of Chemistry
University of Texas, Austin

Canadian Chemical Exec Bélanger Discusses Prospects for Free Trade

Earlier this month, tired negotiators from the U.S. and Canada managed to put together a historic free trade agreement between the two countries. Details of the agreement are still sketchy, and it may take some time before businessmen on both sides of the border are able to assess the agreement's impact on them.

Although the U.S. chemical industry never came out against a U.S.-Canadian free trade agreement, it never was a staunch supporter of the idea either. In Canada, however, the chemical industry was one of the trade agreement's strongest advocates. This support funneled from the Canadian chemical companies to the relevant Canadian government agencies through the Canadian Chemical Producers' Association (CCPA), which is Canada's equivalent to the Chemical Manufacturers Association in the U.S.

Before trade negotiators actually reached an agreement—in fact, during a touchy period in the negotiations when it appeared that they might not reach agreement—C&EN senior editor Earl Anderson spoke with CCPA's president Jean M. Bélanger about the free trade agreement and why Canada's chemical industry has been such a strong supporter.

Bélanger's position as CCPA's chief administrative officer puts him squarely in the middle of the chemical industry-government interface in Canada. A chemical engineering graduate from the University of Ottawa, he also spent 20 years in the Canadian government before joining CCPA. That included five years as director-general of the chemicals branch of the Department of Industry, Trade & Commerce.

What is CCPA and what does it do?

CCPA probably would be best understood as a parallel, albeit on a smaller scale, to the Chemical Manufacturers Association (CMA) in the U.S. Broadly, we deal with the same kinds of people—the chemical manufacturing base in Canada. Companies must make a chemical product in Canada to qualify for membership. We have about 70 member companies, which represent close to 90% of the value of chemical production in Canada.

When you say they must make a chemical, does that exclude such companies as fabricated plastics products producers?

That's right. We go up to and include the resins producers, but producers of plastics fabricated products would not be eligible. Neither would companies that make formulated pesticides, nor paints and coatings. These companies have their own associations. In



fact, the association structure in Canada is quite similar to that in the U.S.

Yet, StatsCan (Statistics Canada, the "Census Bureau" of Canada) includes fabricated plastics products in its chemical trade statistics.

StatsCan is very good at dealing with the more traditional products, such as steel or pulp and paper. But the chemical industry's product lines have evolved so much that StatsCan has not caught up with some of these things. I think it is doing a very good job in many aspects, but in terms of truly representing the chemical industry through its statistics, I don't think it is there yet.

I gather from some of the statistics that I receive from the Department of Regional Industry & Economics that its chemical people take StatsCan numbers and reassemble them into something that's more representative of the Canadian chemical industry.

That's right, they do. And so do we. I think that we (CCPA) have the most extensive data available on the Canadian chemical industry. We break the industry down into three basic groups—petrochemicals, inorganics, and organics/specialties. Lines are not absolute, of course, but I think that our data present a pretty accurate picture of the Canadian chemical industry.

And what does that picture show?

It shows a chemical industry in Canada with sales in the \$8 billion to \$9 billion range. I'm speaking Canadian dollars here.

You mentioned the parallel between CCPA and CMA. I gather that there are frequent meetings between the two organizations. How did this come about?

First, one point. We have a lot of respect for CMA. It has created and received a lot of credibility for the U.S. chemical industry. It has taken a positive approach in presenting the chemical industry as a responsible industry. Our affinity for CMA comes from

Many are "technical issues"—occupational health, the environment, regulatory—and they are cropping up all over the world

the fact that we have a lot of respect for its views. So we have found it very easy to deal with CMA. That's the first point and I think CMA deserves credit.

Second, we must recognize that many issues transcend national borders. Many are "technical issues"—occupational health, the environment, regulatory—and these issues are cropping up all over the world. So a lot of people have to talk with each other, be they government, be they industrialists, or be they private or public interest groups. It is in these areas that CCPA and CMA became most intensively involved at the start.

It sounds as if you two are trying to solve mutual problems rather than adversarial problems.

Very much so, particularly on the technical side. On the business and economics side, we've had a more general approach. CMA president Robert Roland and I have met periodically and we exchange correspondence. Here again, we are being driven to look at issues to see how we are going to deal with them.

Very obviously, one of the major issues now is the proposed Canadian-U.S. free trade agreement. It certainly is for us, and we would hope that it is for the American chemical industry as well.

On this one, we have had meetings with CMA, first to make sure that we understand each other. What's this all about? What's in it for the Canadian chemical industry? What's in it for the U.S. chemical industry? At the start, the meetings were very general. Lately, we have gotten more specific.

For example, how do you deal with rules of origin? If there is a free trade agreement, our American friends don't want Canada to become a back door for products made in other countries to enter the U.S. duty-free. And we don't want the U.S. to be a back door for Canada, either. This is a genuine concern for both of us.

The U.S. chemical industry certainly has other concerns about the trade agreement.

Oh, yes. We recognize the concerns in the U.S. about investment [restrictions] in Canada. We recognize concerns about our energy policy. These are fundamental for any chemical industry. Americans, though, tend to look at our old Foreign Investment Review Agency (FIRA) and say: "If we can't invest in Canada, then we have a major problem with FIRA." But to my knowledge, there never was a foreign investment proposal in the Canadian chemical industry that was turned down by FIRA. Even though FIRA created a bad image in the minds of many U.S. chemical companies, it never did anything detrimental to them.

Is FIRA now history?

Yes, and I think that its replacement, Investment Canada, is sending signals that we really need further investment and that we're talking about investment from anywhere. The door is really open, and I don't think that anyone in the Canadian chemical industry ever did look at where the financing was coming from. Nor do I think that they are doing that now. All we want are good corporate citizens in Canada, just as you want good corporate citizens in the U.S.

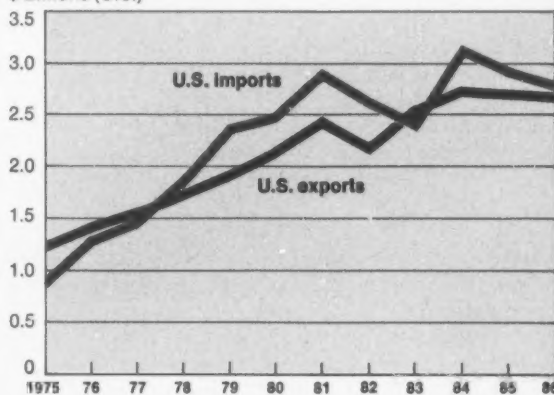
But foreign investment is only one sticking point in the free trade agreement. What are some others?

There are quite a few others, but I want to make one very important point. Canada is still the largest market for U.S. exports—for chemicals, for all products. We are a bigger market than Japan, although many Americans don't realize that. We are also a growing market, whereas some of your other markets have been declining, particularly in developing countries.

In fact, we're both each others' best customers. At the same time, there are some trouble spots. And all we're saying is that there must be some way for these

Canada runs slight chemical trade surplus with U.S.

\$ Billions (U.S.)



Source: U.S. Department of Commerce

two best customers to talk to each other and arrive at conclusions that are mutually beneficial.

It's obvious that the Canadian chemical industry favors a free trade agreement. But what about the corollary? Do you think that the U.S. chemical industry is as much in favor?

First, the trade agreement has been a much more visible issue in Canada than it has been in the U.S. It is much more the center of our focus up here. You

It's important to recognize that the Canadian chemical industry is oriented toward a free market economy

have evidently had other issues that command your attention in the U.S.

But, when you reduce it to the chemical industry per se, no, I have not seen that the American chemical industry is against the trade agreement. Based on discussions that I have had, I think that there's an awful lot of convergence about what we are seeking. We may differ on some details, however.

Just why is the Canadian chemical industry so solidly behind the free trade agreement?

First, let me say that I do not think that Canada will achieve major gains in chemical exports if there is a free trade agreement. But it is going to provide a solid base. I don't foresee a major imbalance in chemical trade between the two countries under such an agreement. There could be some rationalization, but that could benefit both of us. There'll be a lot more competition.

Certainly we want to feel more secure about our market opportunities in the U.S. Obviously, we would like to increase our chemical exports to the U.S. But, under a free trade agreement U.S. chemical companies should be able to export more to Canada as well. And you will get security of supplies in our ever-changing world.

It's important to recognize that the Canadian chemical industry is oriented toward a free market economy. In Canada, the government plays a very little role in the chemical industry. In fact our industry has worked to mold government policy toward a market-driven economy.

You'll recall that a few years ago we had something called the Petrochemical Industry Task Force Report. I know that that report captured some interest in the U.S. What's interesting is that the report, representing an industry, asked the government not to meddle in the Canadian petrochemical industry. We wanted to be allowed to play in a free market. All of the report's recommendations pointed that way.

We wanted deregulation of energy. We wanted free

markets. We wanted deregulation of transportation. We wanted, if you will, deregulation of trade. We certainly don't want protection. And I should point out that the government has moved on just about all of our recommendations. Some have been accomplished; some are on their way to being accomplished.

The Canadian petrochemical industry has favored some sort of free trade arrangement with the U.S., originally sectoral free trade, dating back to the Tokyo round days in the late 1970s. But what about other segments of the Canadian chemical industry? Some companies, particularly in the downstream, or specialties, areas were less than enthusiastic about a free trade agreement. Has this changed?

There is no doubt that the Canadian petrochemical industry has had a long-standing interest in freer trade with the U.S. As far as the other sectors of the chemical industry are concerned, these are smaller companies. And it is not unusual for them to oppose a situation that will require them to make some very major changes in the way they will be doing business.

Broadly speaking, however, the Canadian chemical industry is in favor of free trade. All I'm saying is that some companies are going to have a lot of trouble under a free trade agreement. They will need as long an adjustment period as possible, maybe 10 years out on the horizon.

You're talking about a 10-year phase-in of tariff cuts?

Yes, but they may also need to get a little additional help—whatever is allowed for them under a free trade agreement. But even within the specialties sector, there's a good number of Canadian companies that say, "Yes, we can compete. We'll have to change a lot, but we can and we will."

Granted the Canadian industry supports a free trade agreement. What caveats are attached to that support? What have you told your negotiators to be sure to get?

I already mentioned the rules of origin. That's one

There is no doubt that the Canadian petrochemical industry has had a long interest in freer trade with the U.S.

preoccupation that we share with the U.S. chemical industry. Another important area for us is dispute settlement. We have to have a clear understanding of what we can do and what we can't do. We have the GATT (General Agreement on Tariffs & Trade) rules but they can be interpreted 10,000 different ways. And they can be detrimental to you as well as to us. If

you go to GATT with a complaint, we get mad at you. If we go, you get mad at us. If we don't go, somebody else gets mad—sometimes our own people.

What about the issue of subsidies?

Here we have to define what is a subsidy, and what is not. Sometimes it is very easy for someone to say that something is a subsidy. Some people in the U.S. point fingers at our regional development programs. But, in the U.S., you also have forms of regional aid. You have municipal bonds at very low interest rates. These

We need somebody—some forum—to step in and decide that, yes, that's a subsidy under the terms of the agreement

are really subsidies. So when you say no more subsidies, are these to be stopped as well? The whole agricultural sector is permeated with subsidies.

We in Canada have a perception that some of your defense spending has been used to promote regional development. Defense-oriented plants have been located in certain areas—sure, for defense but also for regional development. So when you say no subsidies, we have to be sure that we understand each other.

So what are you suggesting?

We're saying, let's get more certainty in our relationship. That way, we won't always be fighting, which is so counterproductive. Once we define the rules, there will always be interpretations. Was that bad or wasn't it? So we need somebody—some forum—to step in and decide that, yes, that's a subsidy under the terms of the agreement. And that's not. This is what we call binding dispute settlement.

Will this dispute settlement mechanism be a substitute for U.S. trade remedy laws, such as our antidumping law and the countervailing duty law?

If we both agree on what is fair and what is unfair, then it would seem to me that your trade remedy laws should be used only to counter trade practices of other countries. With a binding dispute settlement mechanism in place, that will be the way that we will do trade with each other.

Speaking of subsidies, both the Canadian government and the Quebec provincial government have poured a lot of money into keeping Pétromont afloat in Montreal. Do you consider this a subsidy?

I'd rather you ask the government or Pétromont. Just let me say that there were some major transitional changes going on at Pétromont. As a result, certain actions had to be taken. It's hard to say how people would interpret the Pétromont thing. In any event,

the Canadian chemical industry is on record as opposing subsidies.

It sounds like a difficult subject to reach agreement on.

Maybe, but there has to be some flexibility. At times, there may be a need for broad adjustments. But those adjustments should be made on a very broad area.

For instance, say the Canadian government wants to help the Maritime provinces, which, as we all know, have economic problems. Whatever the government does should deal with the broad problems of the area. By doing so, it might interest someone to invest in the area or to continue producing there. The help shouldn't be aimed at a particular company. When you do that, not only will American industry complain, but the rest of the Canadian industry that competes with that company will complain as well. We favor a noninterventionistic approach, but where adjustments are necessary, keep them on as broad a basis as possible.

Any other thoughts on a free trade agreement?

We really hope that the American chemical industry will see the benefits it can achieve under this kind of an agreement—benefits not only between Canada and the U.S. though these are major benefits. But another question is how the U.S. will be perceived by the rest of the world. Your government leaders keep saying that the U.S. is willing to trade with anybody provided there is a level playing field. Well, the free trade agreement will provide a level playing field. And because it will, it will be a signal to other countries that they meant what they said.

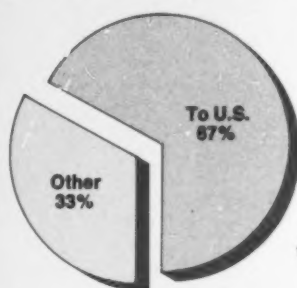
Before we leave the subject of trade, I notice that Canada's chemical trade deficit worsened last year and the latest available statistics indicate that it may get even worse this year. Is the Canadian chemical

We are indeed optimistic that we can be full-fledged participants in the future growth of the international chemical industry

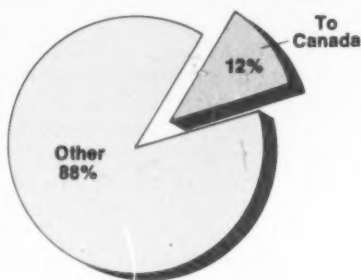
industry becoming less competitive on an international level?

We have to divide that chemical trade deficit into the three components that I mentioned earlier; that is, petrochemicals, inorganics, and organics/specialties. In specialties, the trade deficit is very large, and growing. It now runs about \$1.8 billion (Canadian) a year. So in this area, we recognize that we are going to have to make some changes to adjust to a new business environment if there is a free trade agreement. A lot of specialty chemicals are not made in Canada

U.S. is much larger chemical market for Canada ... than Canada is for U.S.



1986 Canadian chemical exports = \$3.99 billion (U.S.)



1986 U.S. chemical exports = \$22.8 billion (U.S.)

Sources: U.S. Department of Commerce, Statistics Canada

because the market is too small. So it's not surprising that imports are coming in.

It's generally true that, when a country's economy is growing, it imports more. And the Canadian economy is doing very well these days. As a result, a lot of these specialty chemicals are being brought in to meet increased demand of the industries that use them. So a significant part of the increase in imports reflects our economy.

What about the other sectors?

Inorganics are just about in balance, perhaps a little bit positive. The situation in inorganics trade really hasn't changed all that much over the years. Looking at petrochemicals, we see that, 1986 versus 1985, exports are down in dollar terms, but up in volume terms.

One major point, though. When you look at our total chemical exports in volume terms, they increased slightly more than 2% last year. So we believe that we have been able to maintain our international market share.

Is that trend carrying over to this year?

I'm not familiar with the statistics for 1987. What I do see, however, is that profitability, both on exports and domestic sales, is improving. You recall that 1982, 1983, and 1984 were disastrous years, even 1985. In 1986, profitability came back a little bit. But this year, with energy deregulation almost in place, with changes that our companies have made to improve productivity, and with firmer prices, chemical company profits are looking good.

Will those improved profits trigger a new round of direct investment in the Canadian chemical industry?

For some chemical sectors, such as specialties and inorganics, I think that what happens with the trade agreement and what they will have to do to adjust to it will be more important than current profit levels as far as investments are concerned. On the petrochemi-

cal side, I believe that the lack of new investment over the past few years was the result of poor international markets rather than profits.

What you're saying, then, is that overcapacity was the basic problem for Canadian petrochemicals?

Well, we certainly had to absorb a lot of overcapacity that started coming to a head around 1982. At that time, everybody was making assumptions about the direction of the market that didn't come to pass.

So I would expect that the capacity situation will dictate when new investments will be made. I think that we are getting closer to the point where somebody, somewhere in the world, will start thinking about petrochemical investment.

And we believe that Canada is a good place to invest. Deregulation has helped. And Canada is one of the few countries in the world that is resource-rich and has a stable government.

Alberta Gas Ethylene is going ahead with its long-delayed, third ethylene plant. Is this a harbinger of things to come?

I can't comment on that plant specifically, but it is symptomatic that the people of Canada are not discouraged by the tough, recent past. They are indeed optimistic that we can be full-fledged participants in the future growth of the international chemical industry.

Do you see any Japanese investment in the Canadian chemical industry?

Not yet, but with other Japanese companies investing in downstream industries in Canada, we think that it will only be a matter of time. We think that Japanese chemical companies will follow these downstream companies into Canada, with the idea of supplying these companies in Canada just as they do in Japan. It's also possible that Japanese chemical firms might invest in Canada to export back to their home base, just as they have been doing in other parts of the world.

True, Japanese chemical companies have invested heavily in other parts of the world. Why not Canada by now? You should ask them. But seriously, when the major chemical investments were being made in Canada in the late 1970s and the early 1980s, FIRA was still a major concern to many foreign investors. I imagine that this may have weighed heavily on the minds of the Japanese.

In addition, the very fact that these Japanese chemical companies were investing heavily in these other areas that they considered beneficial to them may have precluded additional investments in Canada. Putting all of these things together, it was just a question of the circumstances at the time. This could change in time, though. □

OCTOBER 26, 1987

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CHEMICAL & ENGINEERING

NEWS

1988 Employment Outlook

Fast-changing technology is
spurring reconsideration of
chemical education
Page 33

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News of the Week

■ **Chemical companies' stocks took a plunge during last Monday's stock market crash, reflecting the general panic rather than the chemical industry's prospects.** Page 6

■ **The Chemical Manufacturers Association issues recommendations on chemical arms treaty, outlining areas such as proprietary information and on-site inspections that it believes need more debate.** Page 7

■ **UNESCO's executive board voted to nominate Spanish biochemist Federico Mayor Zaragoza as the organization's next director general after controversial incumbent withdraws.** Page 7

■ **NIH celebrates its centennial with five days of scientific symposia, an NIH alumni reunion, and several commemoration ceremonies.** Page 8

Business

Mexican chemical industry, boosted by petrochemical reclassification, has increased private investments, production, and exports, as it aims to become internationally competitive. Page 11

Government

Clean Sites Inc., founded three years ago to speed cleanup of abandoned hazardous waste sites, overcomes early obstacles. Page 14

Technology

New fertilizer technology demonstrated by TVA may improve industry's near-term competitive position and long-term success. Page 24

Education

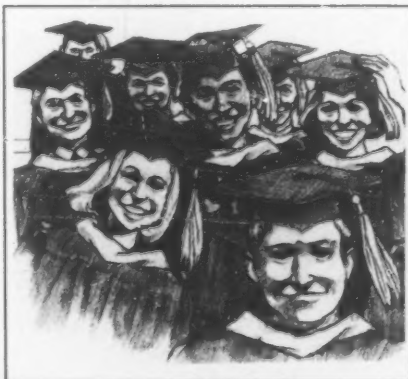
Superconducting levitation kit brings excitement and magical aura of new science experiment into the classroom. Page 32

Awards

ACS award winners: Andersen, Barton, Bernstein, Bockris, Brenner, Breslow, Bruice, Calas, and Castleman. Page 70

Cover: Photo by Ron Sherman/Uniphoto
Picture Agency

Letters	4
Concentrates	
Business	9
Government	13
Science/Technology	22
The Departments	
ACS Comment	62
ACS News	65
New Products	76
Meetings	94
Newsclips	96



Employment Outlook

C&EN's annual look at the job market highlights proposed restructuring of chemical education to better prepare students for work in new high-technology areas. Page 33

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LETTERS

Aspartame and seizures

SIR: As president of the Epilepsy Institute of New York, I empathize with John S. Connolly in his search for the underlying cause of seizure disorder in his 20-year-old daughter (C&EN, Sept. 7, page 4). However, C&EN readers should know that, contrary to Connolly's anecdotal report, the weight of scientific evidence to date simply does not support a link between aspartame and seizures.

The Epilepsy Institute, a not-for-profit organization devoted to people suffering from seizure-related problems, has reviewed the scientific research on aspartame and concluded that the ingredient is safe for people with epilepsy. After reviewing records of some 5000 client visits to the institute, the professional advisory board concluded that there has been no change among seizure pattern of individuals, many of whom use aspartame.

The Epilepsy Foundation of America informs persons that "medical authorities who have reviewed the literature have found that, at this time, there is no scientific documentation to establish a cause and effect relationship between aspartame and seizures." The American Medical Association, American Academy of Pediatrics, American Diabetes Association, and regulatory authorities in more than 60 countries worldwide also have concluded that aspartame is safe.

Anecdotal reports of seizures in humans have been investigated by the Food & Drug Administration and the Centers for Disease Control. In a 1984 report, CDC concluded that there was no consistent or unique pattern of symptoms that would indicate a causal link between the symptoms and aspartame consumption. In its review of 175 seizure reports since the CDC analysis, FDA concluded in 1986 that there is "no consistent association between occurrence of seizures and exposure to aspartame-containing products."

Approximately 1% of the American population suffers from seizures. Epilepsy is second only to stroke as the leading neurological disorder affecting the U.S. population. Seizure susceptibility can be related to high fever, allergic reactions, drug and alcohol withdrawal, hormone variations, and a variety of other factors.

Under these circumstances, and because aspartame is frequently consumed by large numbers of people, it is not surprising that FDA concluded in 1986 that "there may be a chance occurrence of seizure activity following ingestion

of aspartame by seizure-prone people. Such a happenstance, however, is not indicative of a causal relationship between consumption of aspartame and the onset of seizure activity."

As a scientist, Connolly should know that reports of alleged adverse effects from aspartame have not been reported as widely in scientific journals as in the popular press because such anecdotal reports are not based on conclusive evidence of cause and effect. There is no way to determine whether individuals would have linked seizures or other maladies to aspartame prior to hearing publicity about such alleged effects.

Studies are under way at Mt. Sinai Medical Center and Yale University to evaluate the specific neurological condition of individuals who have reported seizures, and for whom physicians have not been able to diagnose other causes.

In summary, we at Epilepsy Institute certainly want to evaluate carefully any allegation relating to the health of our patients. After examining the weight of scientific evidence in this area, we continue to affirm that aspartame is safe for persons with epilepsy.

Ira Brody
President
Epilepsy Institute, N.Y. City

Combustion chemistry

SIR: We were delighted to see the recent special report, "Combustion Chemistry" (C&EN, Aug. 31, page 22) relate the significance of the Brookhaven flash photolysis-shock tube (FP-ST) experiment. Jim Miller and George Fisk accurately reported that the FP-ST method circumvents the problem of isolating elementary reactions that is common with conventional shock tube methods. Indeed, the Brookhaven FP-ST apparatus has produced rate constants for several elementary reactions [Michael, J. V., Sutherland, J. W., Klemm, R. B., *J. Phys. Chem.*, **90**, 497 (1986); Sutherland, J. W., Michael, J. V., Klemm, R. B., *J. Phys. Chem.*, **90**, 5941 (1986); Sutherland, J. W., Michael, J. V., Pirraglia, A. N., Nesbitt, F. L., Klemm, R. B., "21st International Symposium on Combustion," Combustion Institute, in press] at the highest temperatures attained to date via a direct method.

Unfortunately, the authors were less than thorough in giving credit for the development of the FP-ST method. First, the work of Reinhard Zellner and coworkers [Ernst, J., Wagner, H. Gg., Zellner, R., *Ber. Bunsenges. Phys. Chem.*,

Mexican Chemical Outlook Continues To Improve

Petrochemical reclassification boosts private investment, output and exports rise, and imports shrink—all spurring international competitiveness

Earl V. Anderson, C&EN New York

As Leopoldo Rodriguez Sanchez puts it, the Mexican chemical industry came through last year's "test of fire" economic recession with flying colors. Rodriguez, who is president of ANIQ, Mexico's chemical industry trade association, noted at a recent meeting of the organization that, although Mexico's gross national product dropped 3.8% last year, chemical industry output grew 1.2%—five full percentage points better than the overall Mexican economy.

Just as important, that momentum seems to be carrying over into this year. And the enthusiasm that awoke within the industry last year

after a four-year hibernation is still very much alive.

Chemical production is increasing in Mexico, both in the private sector and in Petróleos Mexicanos (Pemex), the government oil company that, by law, produces all primary petrochemicals. Exports are increasing. Imports are shrinking. And the perennial trade deficit that has burdened Mexico's chemical industry may even disappear this year, at least in the private sector. The government wants its chemical industry—a priority industry in Mexico—to become internationally competitive. The industry is taking the challenge seriously.

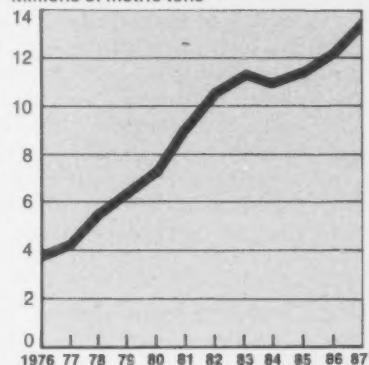
Excluding Pemex's exports and imports of primary petrochemicals, the trade deficit of Mexico's private chemical sector shrunk to \$95.6 million last year. That may sound unimpressive, but it is a hefty 72% less than 1985's deficit of \$342 million. Rodriguez thinks that the private chemical sector deficit can be completely eliminated this year. Nobody is openly calling him wrong.

Several developments have triggered this optimism within the Mexican chemical industry. An important one is Pemex's intention to push ahead with its ambitious petrochemical plant-building program. But perhaps even more important was last year's government decision to reclassify 36 primary petrochemicals as secondary petrochemicals (C&EN, Nov. 17, 1986, page 14).

Rodriguez calls that petrochemical reclassification "the primary structural change" that has occurred within Mexico's chemical industry. What it means is that 36 petrochemicals, including such important products as polypropylene, are no longer the sole domain of Pemex. They can be produced by private companies, including foreign investors.

Pemex's petrochemical output continues to climb

Millions of metric tons^a



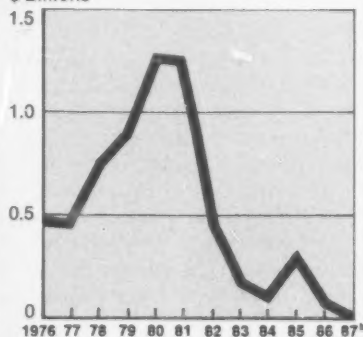
^a Production of primary petrochemicals only.
^b Estimate. Source: Petróleos Mexicanos (Pemex)

The private sector, including several foreign companies, evidently is leaping at the opportunity. According to Alberto Escofet Artigas, undersecretary of mines and basic industry within the Department of Energy, Mines & State Industry, the Mexican Petrochemical Commission has received more than 100 applications for petrochemical investment and building permits during the first nine months of this year. The commission, which must approve all petrochemical projects in the private sector, has already granted 82 new permits so far this year. That's more permits than were granted in the three-year stretch from 1984 through 1986, says Escofet.

Escofet estimates that the 82 plants given the green light so far represent an investment of about \$670 million. They will increase secondary petrochemical production by more than 2 million metric tons—23% of present capacity—and will generate 4500 permanent jobs. They also probably will boost Mexico's private sector chemical exports by

Chemical trade deficit could vanish this year

\$ Billions^a



^a Private sector chemical trade only; excludes primary petrochemical trade of Pemex. ^b Estimate. Source: ANIQ (Asociación Nacional de la Industria Química)

\$500 million per year. What Escofet, or anyone else, is not saying is what products these permits cover. That information hasn't been made public yet. But polypropylene, propylene oxide, acetic acid, acetic anhydride, acetaldehyde, and 2-ethylhexanol are likely candidates.

All of this activity in the Mexican chemical industry is geared to transforming it into a serious international competitor. The goal is to supply, not only the growing domestic market, but the international market as well.

This philosophy is as apparent in Pemex as it is in the private sector. Francisco Rojas, director general of Pemex, says that this is a much better approach than the "old fashioned" plan of just import substitution. As part of what Rojas calls Pemex's "petrochemical transformation," the company will try to minimize the use of crude and maxi-

mize the use of natural gas. It will accelerate construction of petrochemical plants, giving priority to those that will be most productive. It also will give priority to those investments that will guarantee the highest foreign exchange.

It's no surprise that foreign exchange is a high-priority item for Pemex petrochemical management. The company's petrochemical balance of trade deficit dropped 46% last year, compared with 1985. But it still remained at a sizable \$295 million. The good news is that Pemex's imports of primary petrochemicals dropped 43%. Part of the reason, however, is that the company stopped importing these products for resale to the private sector in August 1986. Since then, private companies have had to import their own primary petrochemical raw materials directly.

The bad news is that Pemex's pri-

mary petrochemical exports also declined sharply. They were down 61.5% to \$29 million. The chief culprits were ammonia and ethylene. Exports of each were off 69% last year, yet production of ammonia was down only 14% and ethylene output increased 15%. Pemex officials explain that high domestic demand siphoned supplies away from potential export markets.

Whatever the reasons, Pemex intends to correct the situation. Pemex is building two more ammonia plants, one at Lazaro Cardenas and the other at Camargo. Both plants will have a capacity of 445,000 metric tons per year and will raise Pemex's annual ammonia capacity to 3.8 million metric tons. The two new ammonia plants also fit in nicely with Pemex's plan to take advantage of its huge natural gas reserves.

Construction of the first phase of a major new petrochemical complex at Morelos is expected to be finished by the end of the year and be on stream during the first quarter of 1988. This first phase includes plants to produce ethylene, ethylene oxide and glycol, high-density polyethylene, and acetaldehyde.

Rojas estimates that products from the first-phase plants at Morelos will generate a net trade surplus of \$192 million per year. The remainder of the huge Morelos complex is expected to be completed by 1991. Included will be a 350,000-metric-ton-per-year propylene unit to supply feedstock for acrylonitrile, isopropyl alcohol, and polypropylene, all of which will be produced at Morelos.

By 1989, Rojas says, a 100,000-metric-ton butadiene unit also likely will be on stream at Morelos. Mexico needs this plant badly. Pemex now has only one butadiene plant—a 55,000-metric-ton unit at Ciudad Madero—which can't meet domestic demand. Pemex imported 43,600 metric tons of butadiene last year.

Altogether, the many petrochemical projects that Pemex has in the works probably will generate a trade surplus of \$1.34 billion per year. That's a lot better, says Rojas, than the \$3.3 billion deficit that Pemex would suffer if these projects aren't completed. □

Pemex has ambitious petrochemical plans

Location/product	Capacity (Thousands of metric tons per year)	Status	Location/product	Capacity (Thousands of metric tons per year)	Status
Camargo			Linear low-density polyethylene	80	P
Ammonia	445	C	2-Propanol	75	E
Cosoleacaque			Methyl tert-butyl ether	60	P
Methanol	825	E ^a	Pajaritos		
Lazaro Cardenas			Chlorine	230	P
Ammonia	445	E	Vinyl chloride	300	P
Ethylene	500	P	Ethylene dichloride (direct)	280	P
Propylene	350	P	Ethylene dichloride (oxy)	215	P
Polypropylene	100	P	Perchloroethylene	16	P
Propylene oxide	100	P	Carbon tetrachloride	16	P
Methyl tert-butyl ether	45	P	Perchloroethylene	16	C
Butadiene	60	P	Carbon tetrachloride	16	C
Ethylbenzene	260	P	Salamanca		
Styrene	225	P	Paraffins, C ₁₀ -C ₁₈	60	P
Linear low-density polyethylene	120	P	Olefins, C ₁₀ -C ₁₄	50	P
High-density polyethylene	120	P	Salina Cruz		
α-Olefins	30	P	Benzene	220	P
Morelos			Toluene	365	P
Acetaldehyde	150	C	o-Xylene	60	P
Butadiene	100	E	Mixed xylenes	40 ^b	P
Ethylene	500	C	p-Xylene	240	P
Propylene	27	C	Benzene & mixed xylenes	13 ^b	P
Ethane	705	C	Cyclohexane	120	E ^a
Oxygen	350	C	Cumene	100	P
Nitrogen	60	C	San Martin Texmelucan		
Ethylene oxide	100	C	Acrylonitrile	50	C
Ethylene glycol	125	C	Tula		
Acrylic acid	30	E ^a	Acetonitrile	2	C ^a
Acrolein	6	E ^a	Linear paraffins, C ₁₀ -C ₁₈	60	P
High-density polyethylene	100	C	Olefins, C ₁₀ -C ₁₄	50	P
Propylene	350	E	Other location		
Polypropylene	100	C	Acrylonitrile	50	E ^a
Acrylonitrile	50	C			

Note: C = under construction, E = in engineering, P = in planning. ^a Temporarily suspended. ^b 1000 bbl per day.

Source: Petróleos Mexicanos (Pemex)



Demand

**During the first half of 1987
demand for chemical
professionals was up slightly,
but there are some signs it is
rising more strongly now**

Demand for chemists this year seems to have improved slightly from what it was in 1986. Chemistry department spokesmen characterize the industrial job market for newly graduated chemists as "tough, but not impossible," "okay, but not great," and "seems to be picking up." Many of them add, however, that if the supply of chemists were as large as it was a few years ago, the situation would look much worse.

Chemical engineering departments also report that the job market for B.S. graduates has improved. Many say that at the end of May, 20 to 40% of their 1987 graduates were still looking for work, but that most of them have jobs now. However, some students had to search for a long time before they found work, in contrast to the situation 10 years ago when engineers needed to make little effort to find a position.

In general, the employment market for Ph.D. chemists and chemical engineers is mixed. Candidates from some schools had an easy time finding work, and all found employment by the end of the summer. At other schools, a number of the new Ph.D.s are still looking for work, or else have taken postdoctoral positions only because they failed to locate jobs in industry.

A mixed situation in the job market also is reported by leading chemical companies. Some of them are hiring very few or no new gradu-

ates this year as they continue to trim their work forces. Others have expanded their hiring considerably over what it was last year.

According to the College Placement Council, the numbers of job offers received by B.S. and M.S. chemists and chemical engineers were much lower than they were last year, also not a good year, but the offers for Ph.D. chemists and engineers increased slightly. However, these are offers extended before the end of May and do not include the many jobs that were offered during the summer. Also, they do not include teaching positions.

Because profit margins for chemical companies hit 7% for the first half of 1987 (compared with 5% in 1986 and 4% in 1985) and chemical output is up, it would seem that the hiring situation would have improved more than it has. However, a number of factors have kept the number of new positions low at many companies.

Though the volume of early retirement is not nearly so great as it was last year, many companies continue to reduce their work forces with voluntary early retirement programs begun about two years ago. As a result, a greater-than-usual number of older chemists are still competing with new graduates in the job market. At Du Pont, for example, the companywide program

encouraging early retirement ended this year, but specific areas of the business still are implementing early retirement.

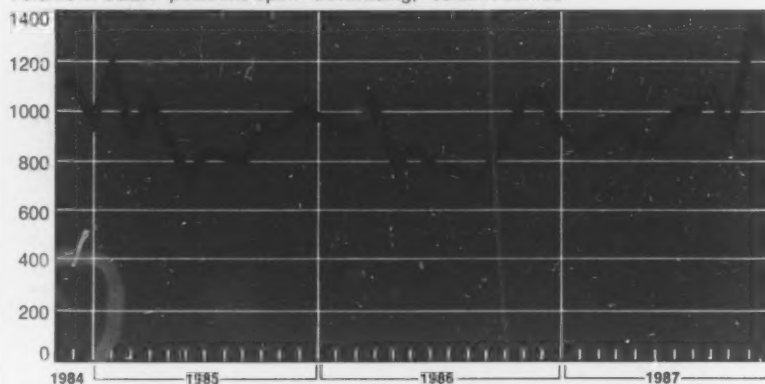
In general, despite increased profits, companies are continuing to struggle hard to increase productivity and efficiency. One of the major ways they accomplish this is by keeping the number of employees as low as possible. Most firms were extremely careful about the number and qualifications of the employees they hired this year. Nearly all university spokesmen contacted by C&EN remark about the extreme caution with which companies were going about hiring. They say requests for a certain number of candidates from chemistry departments used to come from the company as a whole. Now, individual departments of the firm ask for graduates with very specific qualifications.

Further evidence of this cautious approach is that some firms are making job offers later this year than last. To avoid taking on too many new employees, they are hiring in a shorter time frame, tailoring their offers of new positions very closely to the needs directly at hand.

Another factor that depresses the job market is that oil company profits are still low. Oil companies are better off financially than they were a year ago but are still having difficulties. Therefore, they are hiring a few more chemical engineering graduates than they did last year, though not nearly the number they employ traditionally. Compounding the uncertainty for oil companies is the volatile situation in the Middle

Help-wanted ads push higher this year

Volume of C&EN "positions open" advertising,^a column-inches



^a Column-inches published during consecutive periods of four issues each.

East, which could push oil prices up or down drastically over short time periods.

Other unsettling aspects of the U.S. economy that help keep hiring down in spite of increased profits and chemical output are the five-year-long recession in the agriculture sector, the decline in new housing starts of 10% from a year earlier during the first nine months of 1987, and the decrease in automobile production. Each of these sectors has a large effect on the volume of chemicals consumed in the U.S. and consequently on the expectations of the chemical industry.

Recruiters and placement people have the impression that small and midsize entrepreneurial firms are playing a larger role in employment of new graduates in chemistry and chemical engineering. Most of these firms do not have formal recruiting programs. Many of them call a department head in May or in early summer, asking for the names of a few candidates. This, of course, adds to the number of job offers extended late in the year. "Placement people have begun emphasizing small business," says Rebecca J. Simon, placement director at the school of chemical sciences at the University of Illinois. "Most small companies don't realize they can use the placement offices at colleges and universities to locate candidates."

Reports from chemistry departments at major universities give rather varied pictures of the employment situation. Audrey L. Ayles-

worth, placement coordinator in the chemistry department at the University of Wisconsin, Madison, reports the job market was "a little bit down" from what it was last year and that "jobs came through really late." Only one third of the B.S. chemistry majors who used the placement service to locate a job in industry were successful. Those who found work averaged only one job offer per person compared with 1.4 in the previous year. Aylesworth says it is taking B.S. students from six months to a year to land something.

Of the Ph.D.s who used the service, 38% found jobs in industry and 44% took postdoctoral positions. About 17% are essentially still looking for work, either continuing with their Ph.D. research or planning to use the placement service in the fall. Offers from companies came through so late this year that several new Ph.D.s grew impatient and took a postdoctoral position when they would have preferred a job in industry. Later, after committing themselves, some received offers from industry.

Aylesworth believes that mergers are continuing to affect the job market. Newly merged companies are shuffling people around instead of hiring new ones, she says.

At the University of Michigan, the job situation seems slightly better. Leah C. Atwater, director of student services in chemistry, reports that the number of recruiters who came to the campus was down about

25% from last year, but B.S. students who were looking for industrial jobs found them. Ph.D. students "had to work hard to find positions but finally got them." She, too, reports that job offers were coming through later than usual. "Companies are being very, very cautious about who they invest in for the future," she notes.

Demand for chemists showed "moderate to low growth from last year to this year" at the University of Illinois, Urbana. Simon attributes this growth to a slowing of merger activity. "Finally, some of these companies have completed mergers and things seem to be fairly calm," she comments.

In contrast, Bert M. Tolbert, associate chairman of the chemistry department at the University of Colorado, reports that the job market for graduates has been good, even though the number of recruiters sent to the campus was down a little from last year. He says that Ph.D.s specializing in analytical and biochemistry are in the most demand and that positions in physical and inorganic chemistry are adequate, especially in the academic field. "None of the Ph.D.s had much trouble finding a job," he says.

A similar upbeat situation was reported by R. Bryan Miller, chairman of the chemistry department at the University of California, Davis. The job market for both B.S. and Ph.D. graduates "looked quite good this year," he says. He notes that most B.S. candidates who wanted to go into an industrial position were able to obtain employment. All the Ph.D. chemists he is aware of secured an industrial, postdoctoral, or teaching position.

The job market for new chemical engineers also has improved. "The general trend seems to be picking up," notes Ronald Darby, professor of chemical engineering at Texas A&M. Though only 50 to 60% of B.S. graduates at Texas A&M had jobs by the end of May, the vast majority have positions now. However, Darby notes that demand for engineers with advanced degrees is still low. "There are jobs out there," he observes, "but students have to go look for them."

He also says that many compa-

nies offered positions much later this year. "Some firms were looking for one or two people in the spring, but this summer called asking for more candidates. We had a lot of calls directly to the department this summer, especially from small firms," he adds. He received inquiries from individual departments of companies asking for specific specialized candidates. Companies seem to be on a shorter time frame in contrast to past years when they decided early in the year how many candidates they would need, he says.

One very encouraging development, Darby observes, is that oil companies offered so many summer jobs for Texas A&M undergraduates this year that not enough students were available to fill them. He believes oil firms are somewhat concerned that the supply of engineers will not be sufficient in the future.

The size of the B.S. graduating class had a great effect on the appearance of the job market at Virginia Polytechnic Institute & State University. William L. Conger, head of the chemical engineering department, says the market has improved from previous years, but only because there are fewer students. The graduating class shrank from 90 in 1985 to 75 in 1986 and 43 in 1987. Though 75 to 80% of the B.S. students had found jobs by the time they graduated, a few still haven't received an offer. He also notes that companies were offering positions later than usual. "Right at the end of May, suddenly jobs were available," he says.

According to industry spokesmen, the job market for chemists and chemical engineers has improved somewhat, but it is still down compared with historical levels. This, however, varies a great deal with individual companies.

Thomas J. Neelen, manager of college relations and recruiting for Union Carbide, says his company recruited about three times more B.S. chemical engineers and Ph.D. chemists and chemical engineers this year than last. In contrast, the modest need for B.S. chemists remained essentially unchanged from last year.

"In 1986, mediocre business con-

ditions and a major reorganization, with both divestments and an early retirement program, made for an extremely cautious hiring environment," Neelen says. With business conditions considerably improved and the major restructuring completed, recruiting activity at Carbide has become relatively strong.

Similarly, more chemists were hired this year than last at Du Pont. In contrast to 1985 and 1986, when Du Pont hiring was unusually low, 64 new chemists were given positions this year. In addition, Du Pont hired more than seven times as many chemical engineers as it did in 1986. Robert K. Armstrong, manager of professional staffing, observes that "the supply and demand of Ph.D. chemists is now in good balance," but, as usual, "B.S. and M.S. chemists absolutely swamped the market."

At Procter & Gamble the number of new Ph.D. chemists hired was down slightly from last year, but remained near the past four-year average, according to Ted J. Logan, manager of Ph.D. recruiting. From talking with recruiters at a recent conference, Logan concludes that for most companies, demand during 1986 and 1987 was essentially average compared with the previous five years. He notes that the size of the research staff at Procter & Gamble is growing faster in life sciences than in chemistry.

Fred O. Schulz Jr., manager of hiring for B.S. chemical engineers at Procter & Gamble and chairman

of the supply and demand committee for the American Institute of Chemical Engineering, says that, in general, his impression is that demand for B.S. and M.S. engineers is inching up while supply is crashing. Even so, a significant percentage of engineers still can't get jobs. Procter & Gamble hired essentially the same number of engineers this year as last, he says.

A more gloomy picture of the job market was depicted by Ivory Herbert, manager of staffing at Hoechst Celanese, a company created this year by the acquisition of Celanese by West Germany's Hoechst. Hiring of Ph.D. chemists at Celanese has been reduced for the past few years. Only two new Ph.D. chemists and three B.S.-level chemists were given positions this year. Herbert characterizes the market as "extremely soft. Most companies are restructuring and streamlining and automating manufacturing processes. To remain competitive in national and international markets, they are using a high degree of caution in hiring."

Just as the view of the current job market varies somewhat from university to university and firm to firm, the outlook for next year also seems to vary. Tolbert of the University of Colorado expects the job market will improve further. The University of California's Miller agrees. "I think the brighter picture will continue. The worst of the oil companies' problems are over," he says. Texas A&M's Darby says the

Supply of new chemists and chemical engineers shrinks at undergraduate level but rises for Ph.D.s

Academic year:	Degrees awarded in chemistry ^a			Degrees awarded in chemical engineering		
	Bachelors	Masters	Ph.D.s	Bachelors	Masters	Ph.D.s
1974-75	10,649	2006	1824	3142	990	346
1975-76	11,107	1796	1623	3203	1031	308
1976-77	11,322	1775	1571	3581	1086	291
1977-78	11,474	1892	1525	4615	1237	259
1978-79	11,643	1765	1518	5655	1149	304
1979-80	11,446	1733	1551	6383	1271	284
1980-81	11,347	1654	1622	6527	1267	300
1981-82	11,062	1751	1722	6740	1285	311
1982-83	10,746	1604	1746	7145	1304	319
1983-84	10,704	1667	1774	7475	1514	330
1984-85	10,196	1598	1631	7146	1544	418
1985-86	9,893	1592	1737	5877	1361	446

^a Data do not include biochemistry and geochemistry. Source: Department of Education's National Center for Education Statistics

Demand for chemistry faculty at universities rises

Though industrial demand for chemists and chemical engineers is steady or perhaps up slightly, demand for chemistry faculty at universities and colleges seems to have risen substantially over the past few years.

Concrete figures are not available on how demand has changed. However, a survey of current openings was done this year by an ad hoc committee appointed by Edward F. Hayes, former head of the chemistry division at the National Science Foundation. The committee was cochaired by Clayton H. Heathcock and Robert G. Bergman, professors at the University of California, Berkeley.

"There is a widespread belief among department heads that it is getting harder and harder to fill vacancies on chemistry faculties," Heathcock says. "NSF is concerned that inadequate funding of chemistry faculty is causing people to turn away from the profession."

For the survey, a questionnaire was sent to 188 chemistry departments; 156, with a total of 3581 full-time

equivalent positions, responded. The results show that during the past year there were 316 chronic vacancies—positions that have been unfilled for a year or more. The average duration of the chronic vacancy was two and a half years.

The fields in which most vacancies appeared are organic (78), physical (57), analytical (52), inorganic (48), and biochemistry (27).

A National Research Council report on doctorate recipients from U.S. universities says that of the 1631 Ph.D.s who graduated in 1985, only 147 expressed an interest in teaching. Even if the number was somewhat higher in 1987, it likely would not have been high enough to fill the demand.

Many chemistry department heads believe that students are turning away from teaching because they believe that research funding is very difficult to secure in academia. Students also think industrial positions pay better, are more secure, and involve less pressure.

impression he has received from recruiters is that "things are now picking up significantly," and expects next year will be better than 1987.

Logan of Procter & Gamble predicts that hiring of Ph.D. chemists in 1988 will be up slightly from 1987. Armstrong of Du Pont says that "with a solid economy predicted through 1987 and on into 1988, we believe the job market will be good for chemists."

A number of observers expect the hiring situation in 1988 will be almost the same as it was this year. Whatever they see as the current job market seems to carry over into their views of next year. Herbert of Hoechst Celanese, for example, who believes the job market was poor this year, thinks it will continue to be soft in 1988.

Atwater of the University of Michigan shares this view. She sees the current market as difficult and believes the situation will stay the same. Virginia Tech's Conger also predicts no major change next year. In short, though assessments of the

current situation vary, most observers see little change next year.

In its latest employment report, the College Placement Council says that bachelors degree candidates in chemistry received 76% fewer offers, as of June 5, 1987, than they received by the same date in 1986. Likewise, B.S. chemical engineers experienced a 24% decline in the number of offers. However, these figures may represent underreporting by the universities and the later-than-usual dates at which companies were offering jobs rather than a real decline in the volume of offers. Also, they may reflect that small and midsized companies are now playing a larger role in hiring. For doctoral candidates, offers were up 8% for chemists and 28% for chemical engineers.

In contrast to the fall in job offers reported by the College Placement Council, the overall unemployment rate for ACS-member chemists fell from 1.7% in March 1986 to 1.1% in March 1987, a statistic that has not been so low since 1981. The unemployment rate was 1.7% for B.S.

chemists, 1.3% for M.S. chemists, and 0.8% for Ph.D. chemists, compared with 2.6% for B.S.s, 1.7% for M.S.s, and 1.3% for Ph.D.s in 1986. In March, the general unemployment rate was about 6%.

According to the ACS Office of Statistical Services, the unemployment rate for newly graduated B.S. chemists of about 13% was essentially unchanged from last year. For B.S. chemical engineers who graduated in 1987, it has dropped to 18% from 21% in 1986.

AICHE reports that the overall unemployment rate among its members rose from 2.8% in February 1985 and 3.2% in February 1986 to 3.7% in March 1987. However, Trudy Hutter, manager of member employment and professional development services, says the unemployment figure now is down to between 2 and 3%. "My general impression from talking with recruiters and companies all over the country is that the job market is improving tremendously, though I don't have concrete figures," she says.

Audra B. Rafter, manager of the ACS's Employment Aids Office, which operates the ACS National Employment Clearing House, says that the latest clearinghouse at the ACS national meeting in New Orleans in September was the best overall—particularly with respect to employers and employer activity—since the clearinghouses in New York City in 1981 and in Philadelphia in 1984. The ratio of candidates to employers was better than at any meeting since 1980. There were 455 positions posted and 544 candidates.

Recruiters showed the greatest interest in analytical chemists (107 positions listed), organic chemists (82), biochemists (51), postdoctoral chemists (36), polymer chemists (34), chemical engineers (34), physical chemists (22), and teachers (20).

The volume of position-open advertising in C&EN also shows a sudden upturn in demand for chemical professionals. For September, the volume of advertising was higher than it was in any month in the past three years. The number of column inches in the first 40 issues of 1987 was 9708, 15% higher than in the first 40 issues of 1986. □